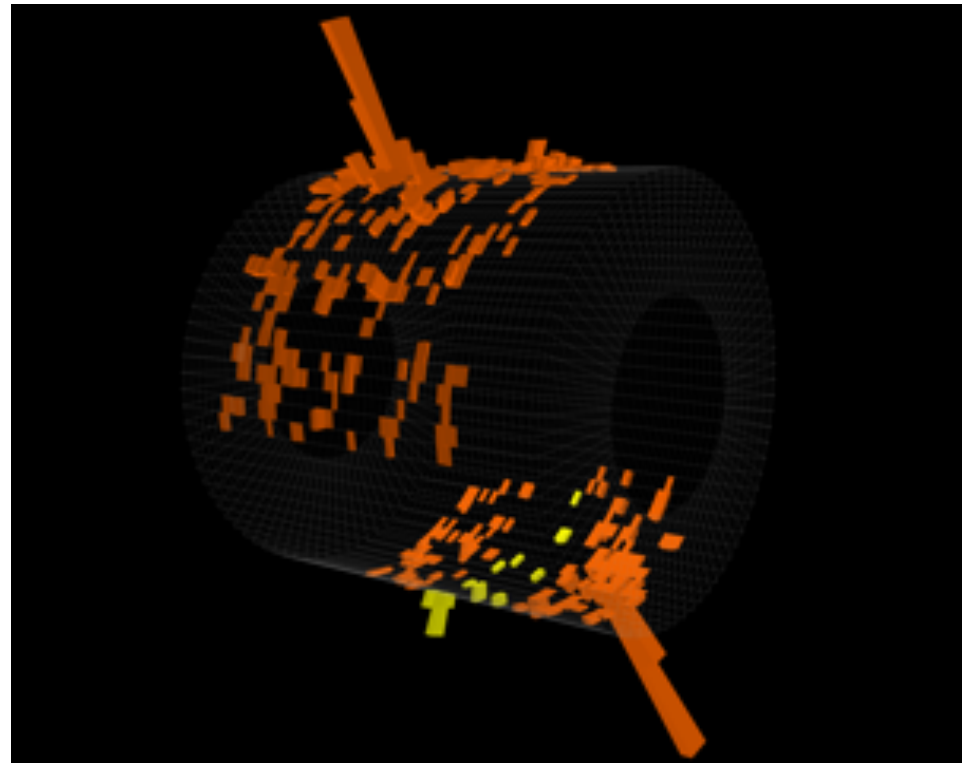


Jet Physics in ALICE



Joern Putschke
for the
ALICE Collaboration
(Wayne State University)





ALICE pp jet x-section measurements and pQCD calculation

“Inclusive jet spectrum for small-radius jets”, arXiv:1602.01110

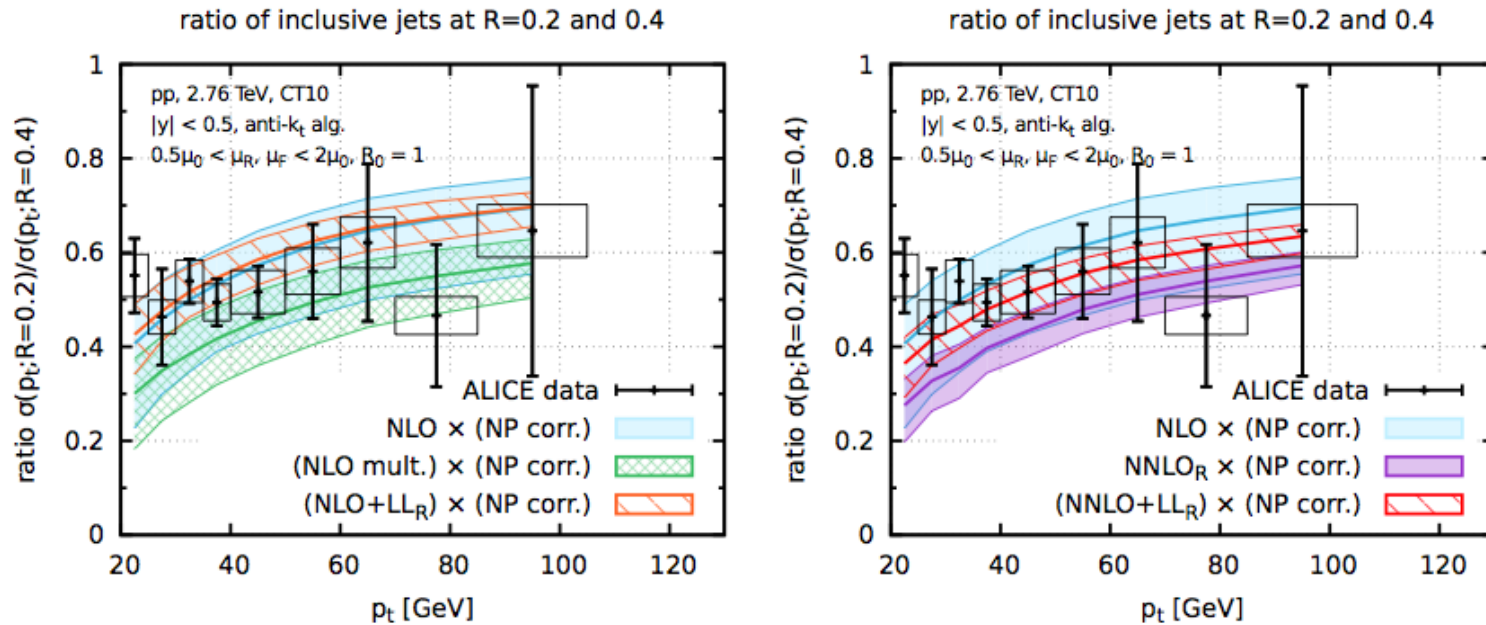


Figure 15. Comparison between a range of theoretical predictions for the inclusive jet cross-section ratio and data from ALICE at $\sqrt{s} = 2.76$ TeV [13]. The left-hand column shows NLO-based comparisons, while the right-hand one shows NNLO_R-based comparisons. Rectangular boxes indicate the size of systematic uncertainties on the data points, while the error bars correspond to the statistical uncertainties.

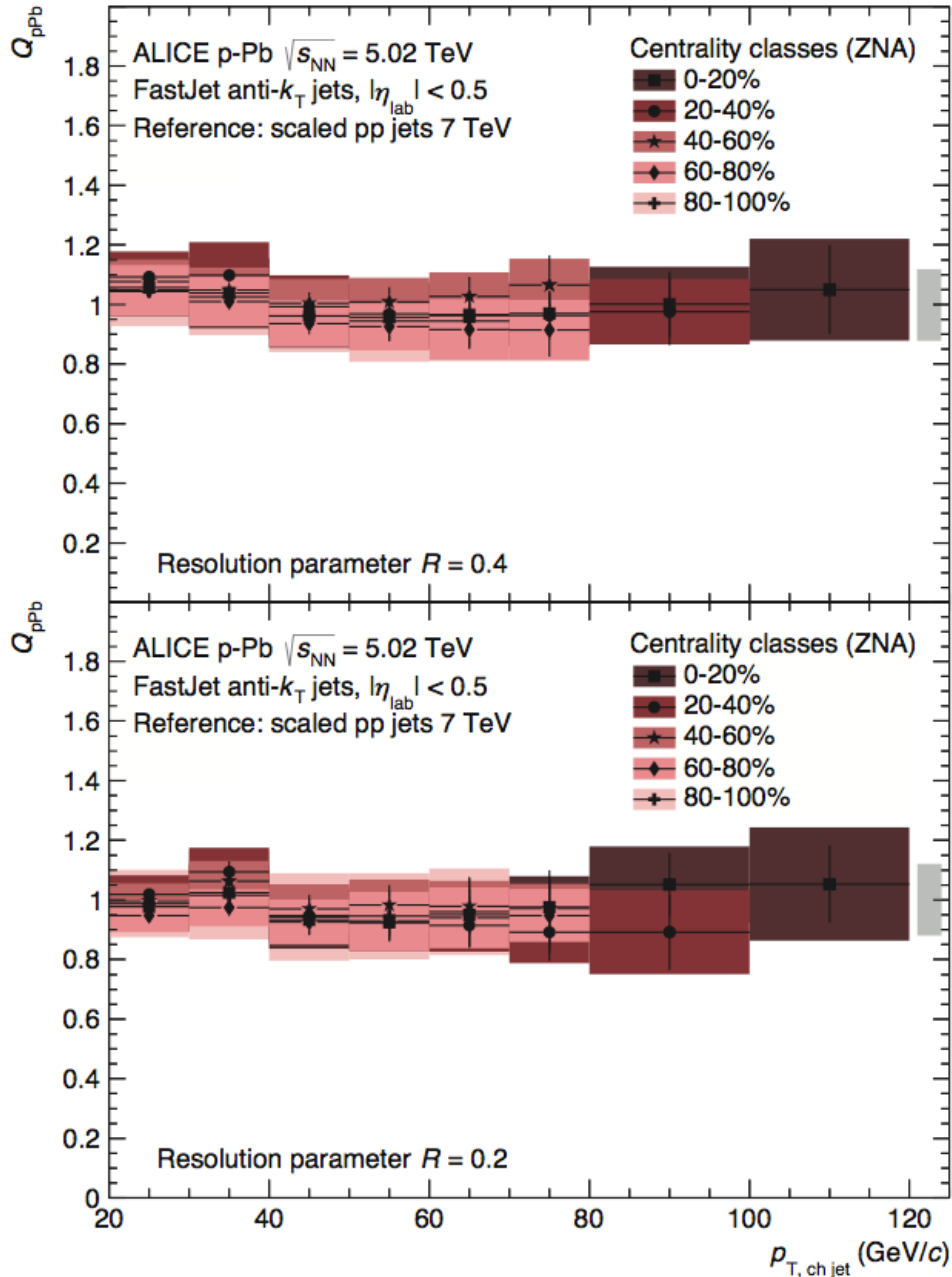
ALICE pp jet x-section measurements, in particular at lower jet energies, can be used to constraint (N)NLO corrections



(Charged) Jet (Q)R_{pPb} vs Centrality

arXiv:1603.03402 (submitted to EPJC);

Detailed discussion of centrality biases in Phys. Rev. C 91, 064905 (2015)



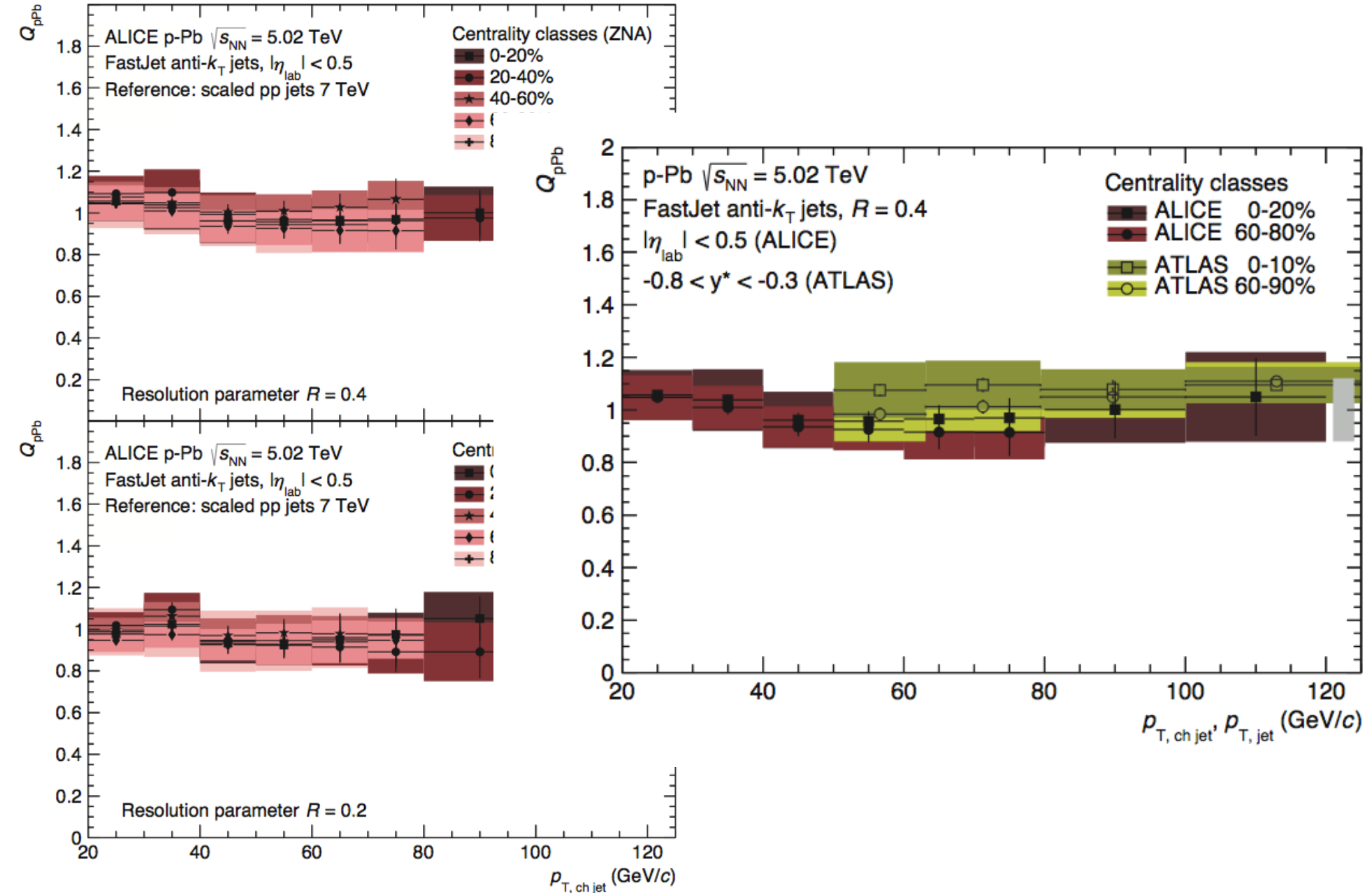
**$Q_{pPb} \sim 1$ for all centralities
and independent on jet p_T**



(Charged) Jet (Q)R_{pPb} vs Centrality

arXiv:1603.03402 (submitted to EPJC);

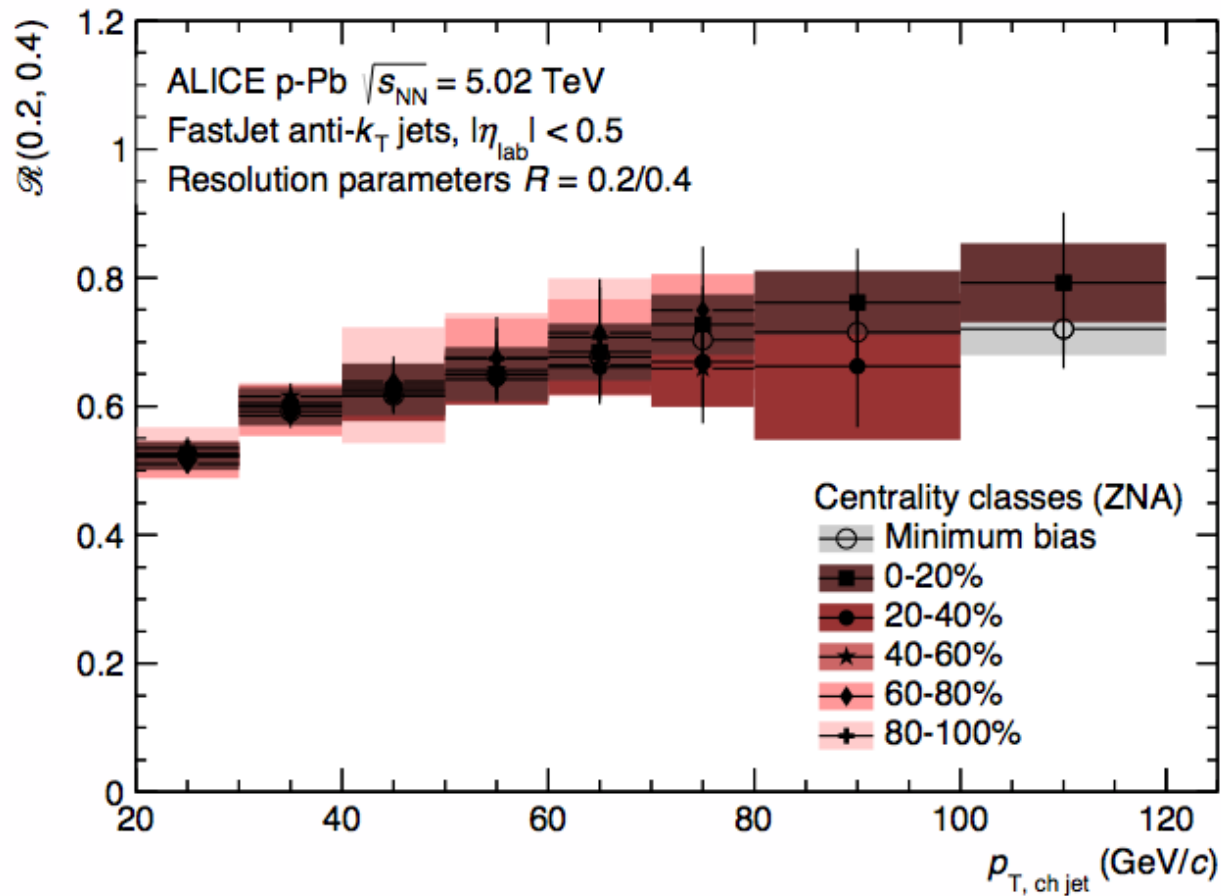
Detailed discussion of centrality biases in Phys. Rev. C 91, 064905 (2015)





Jet Structure Ratio in pPb collisions vs Centrality

arXiv:1603.03402 (submitted to EPJC)



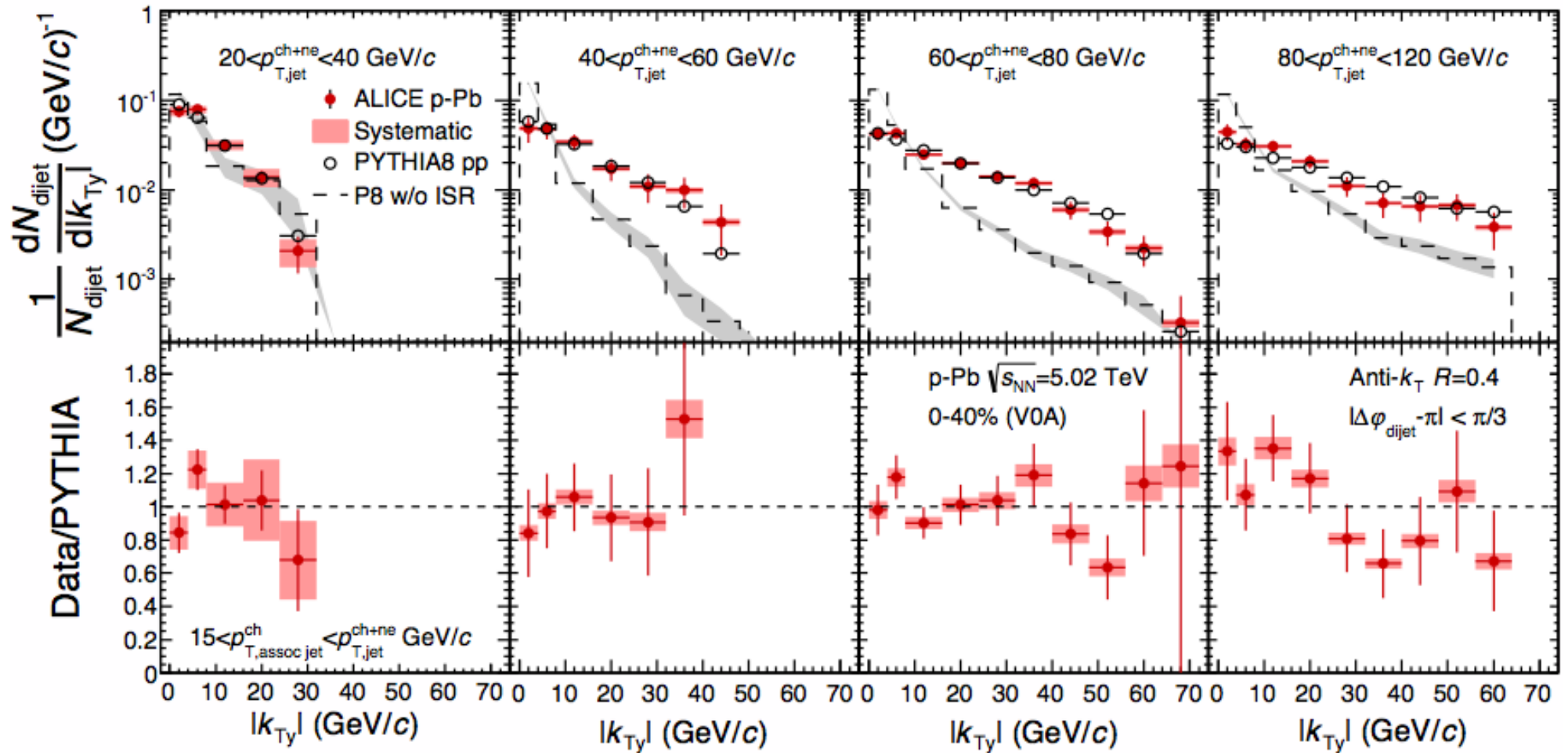
Jet Structure (Ratio: $R=0.2/R=0.4$) consistent with pp expectations



Di-Jet k_{Ty} in pPb collisions

$$k_{Ty} = p_{T,jet}^{ch+ne} \sin(\Delta\phi_{dijet}),$$

PLB 746(2015) 385



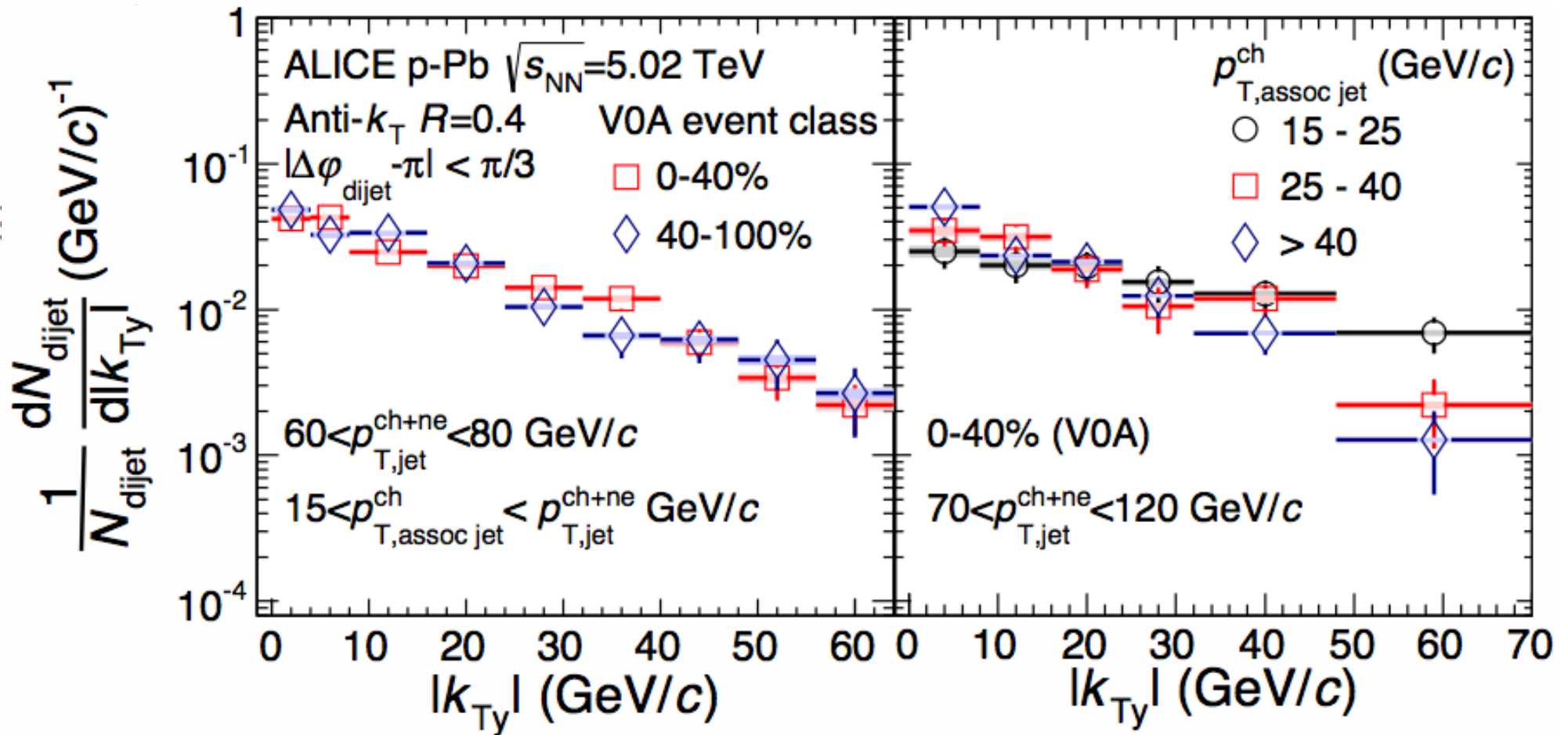
Di-Jet k_{Ty} consistent with Pythia predictions \rightarrow for large Q^2 mainly sensitive to the increased available phase-space for QCD radiation processes



Di-Jet k_{Ty} in pPb collisions

$$k_{Ty} = p_{T,jet}^{ch+ne} \sin(\Delta\phi_{dijet}),$$

PLB 746(2015) 385

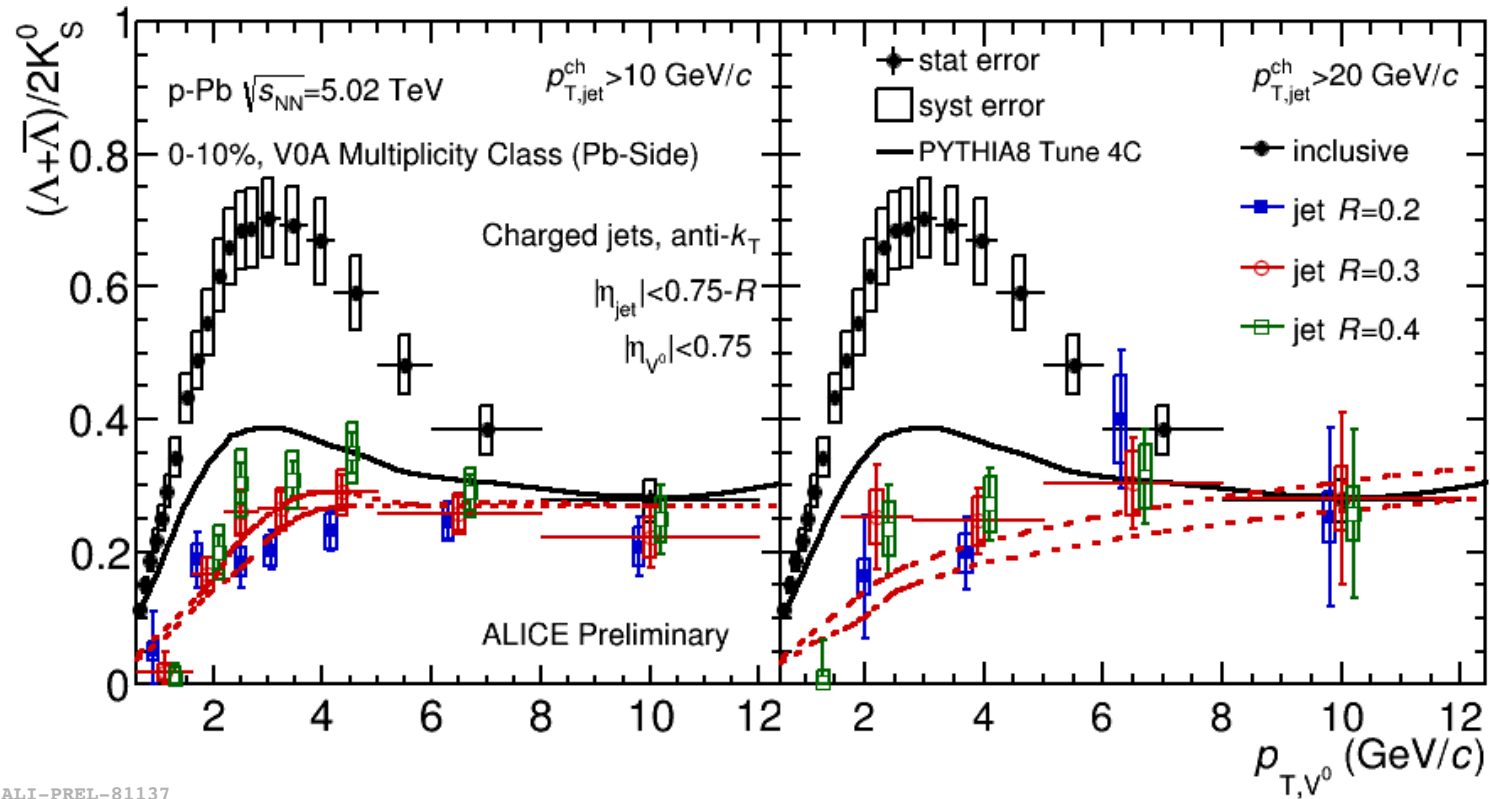


Di-Jet k_{Ty} consistent with Pythia predictions → for large Q^2 mainly sensitive to the increased available phase-space for QCD radiation processes

No centrality dependence observed in pPb collisions



(Light flavor) PID in Jets in pPb



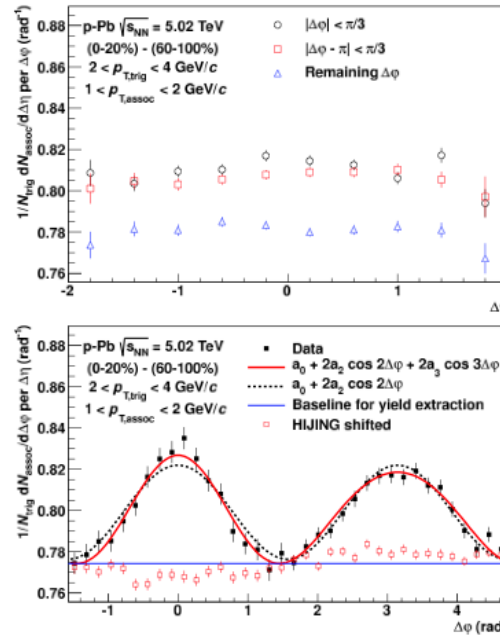
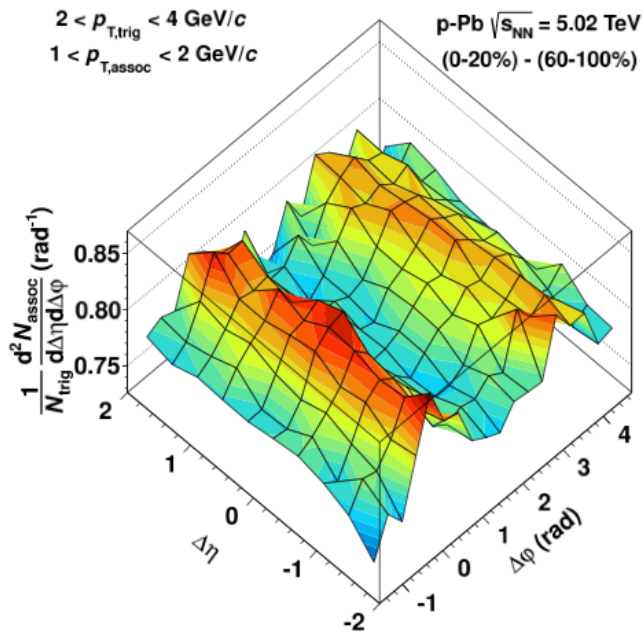
ALI-PREL-81137

**Lambda to K ratio in jets significantly lower than inclusive;
consistent with Pythia expectations (and PbPb results)**



Summary of pPb: Emphasis on Jets

PLB 719 (2013), pp. 29-41



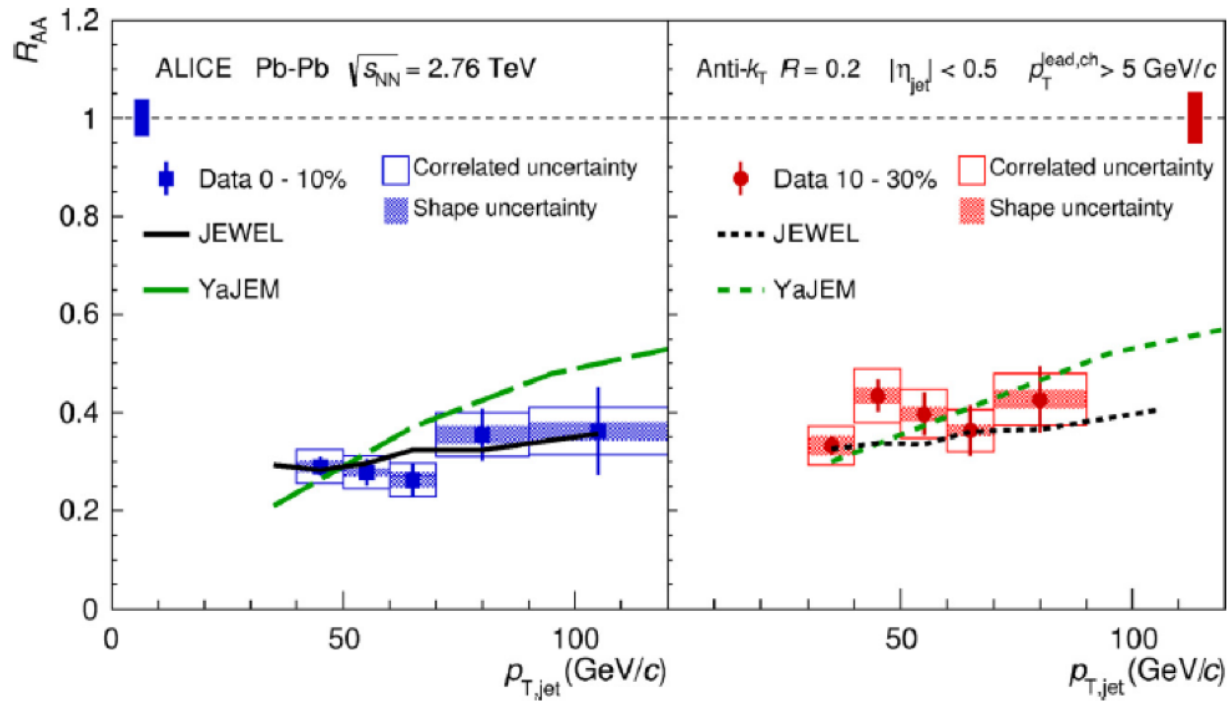
Interesting, collective(?) behavior at low p_{T} seen even in the “small” pPb system!

In contrast: Jets as measured in the available kinematics in ALICE (η , p_{T}) suggest no strong CNM effects!



ALICE Jet Quenching Measurements in PbPb

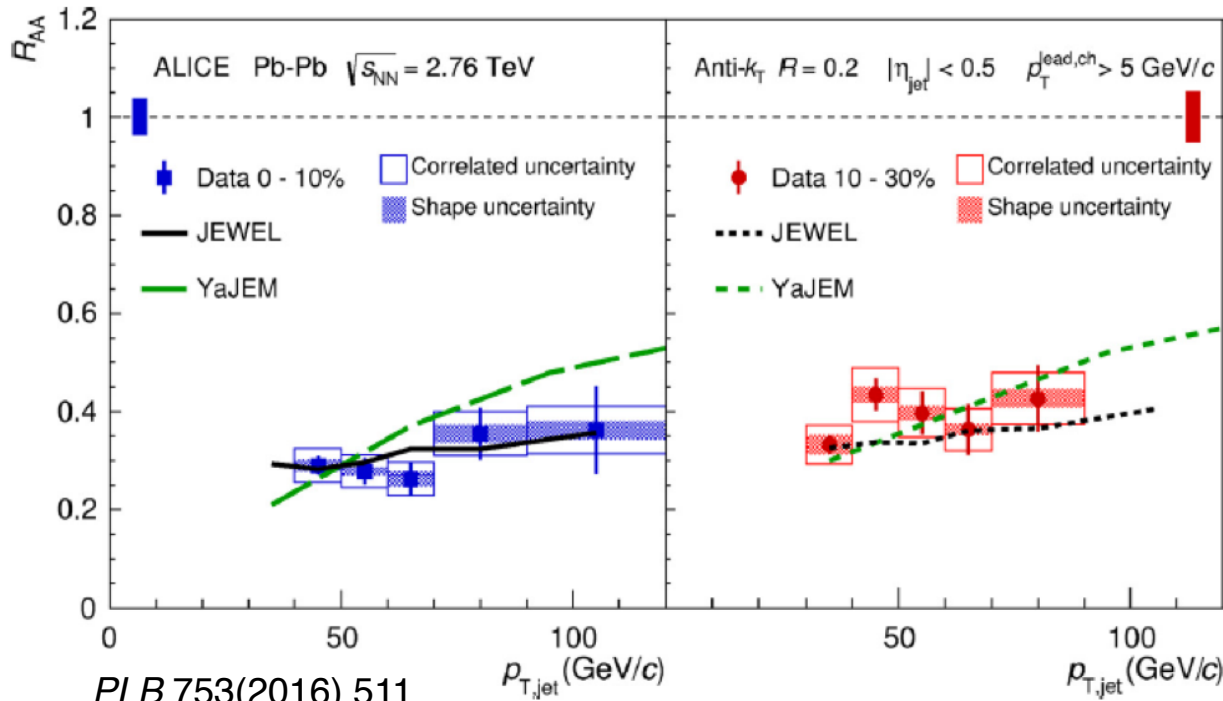
PLB 746(2015) 1



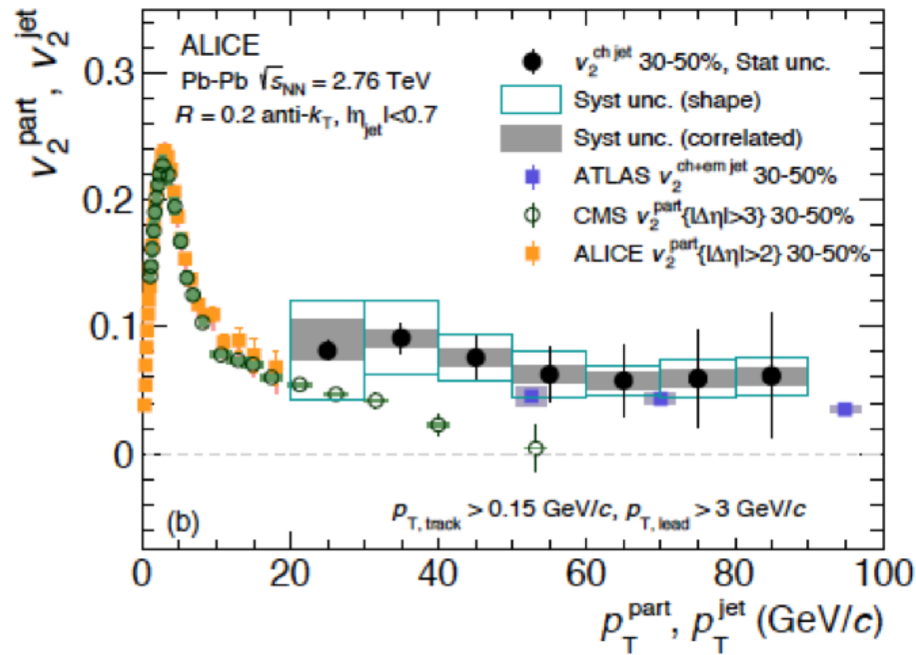


ALICE Jet Quenching Measurements in PbPb

PLB 746(2015) 1



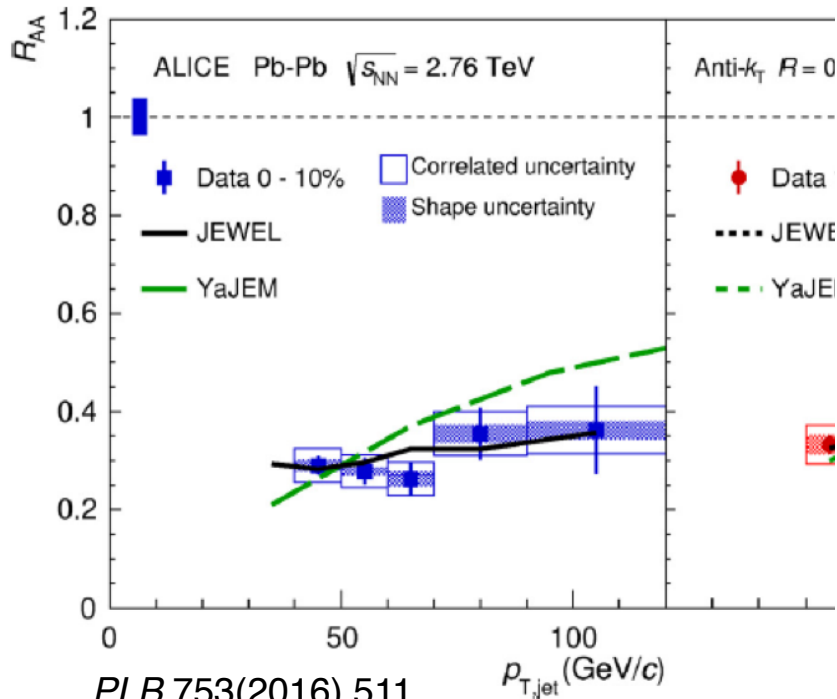
PLB 753(2016) 511



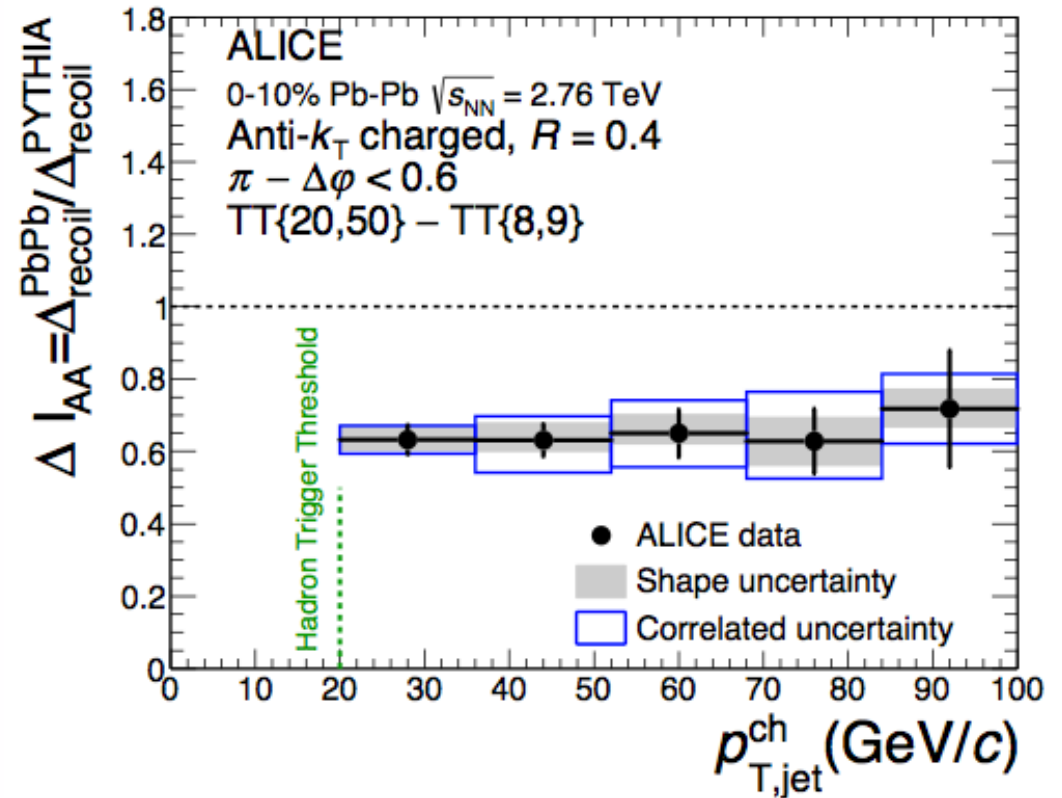


ALICE Jet Quenching Measurements in PbPb

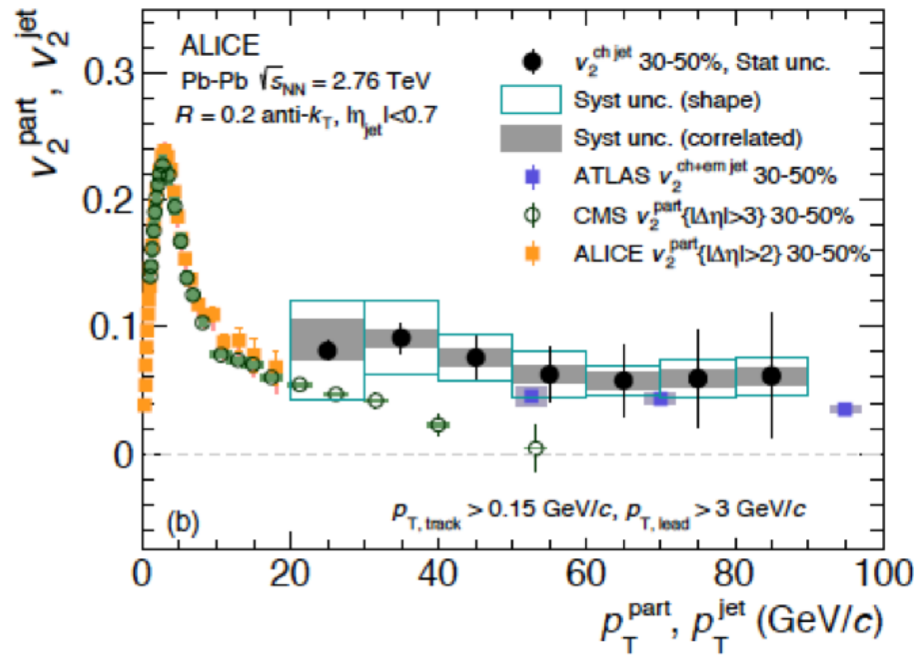
PLB 746(2015) 1



JHEP 1509 (2015) 170



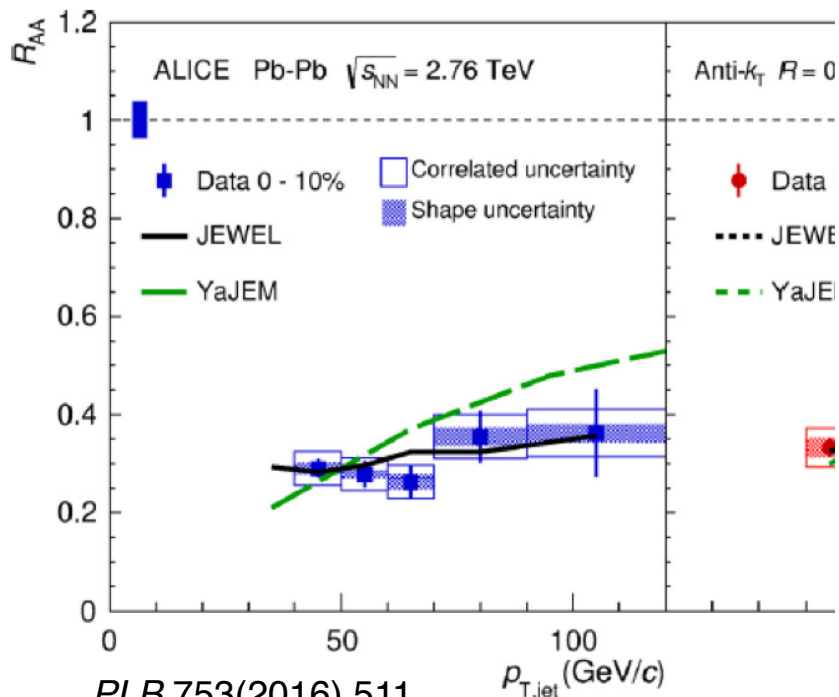
PLB 753(2016) 511



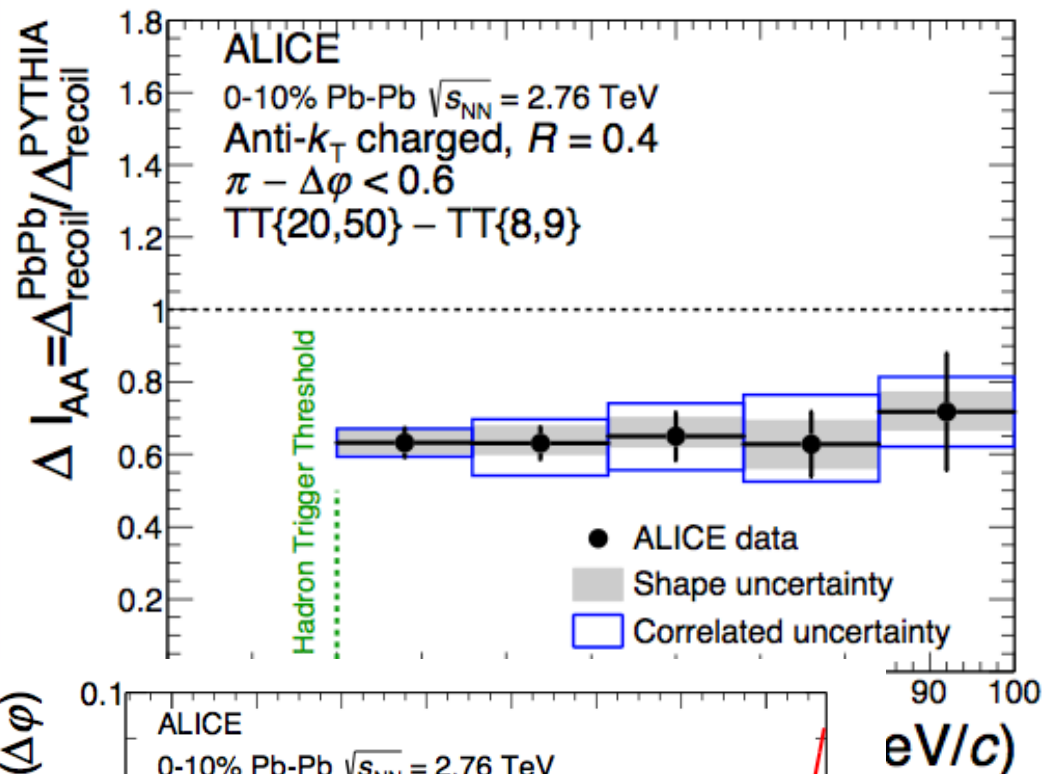


ALICE Jet Quenching Measurements in PbPb

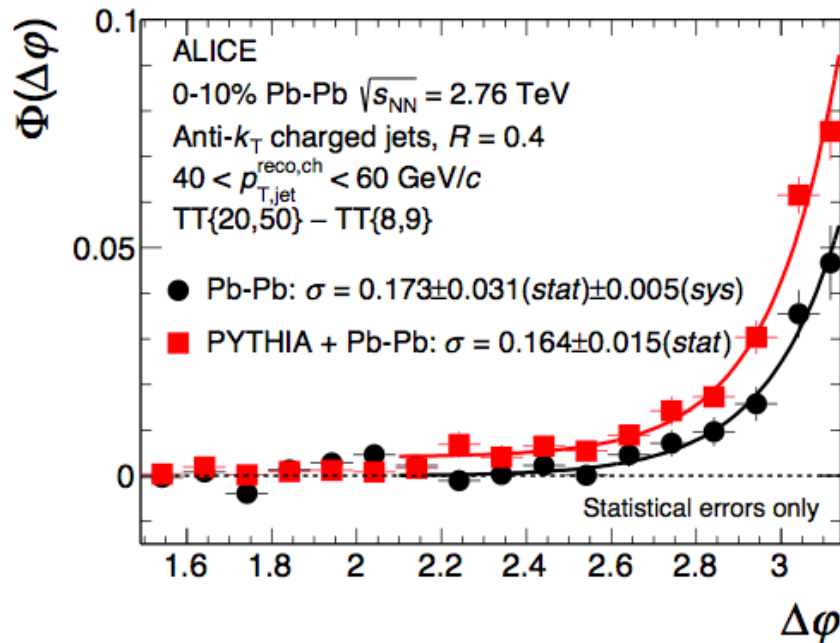
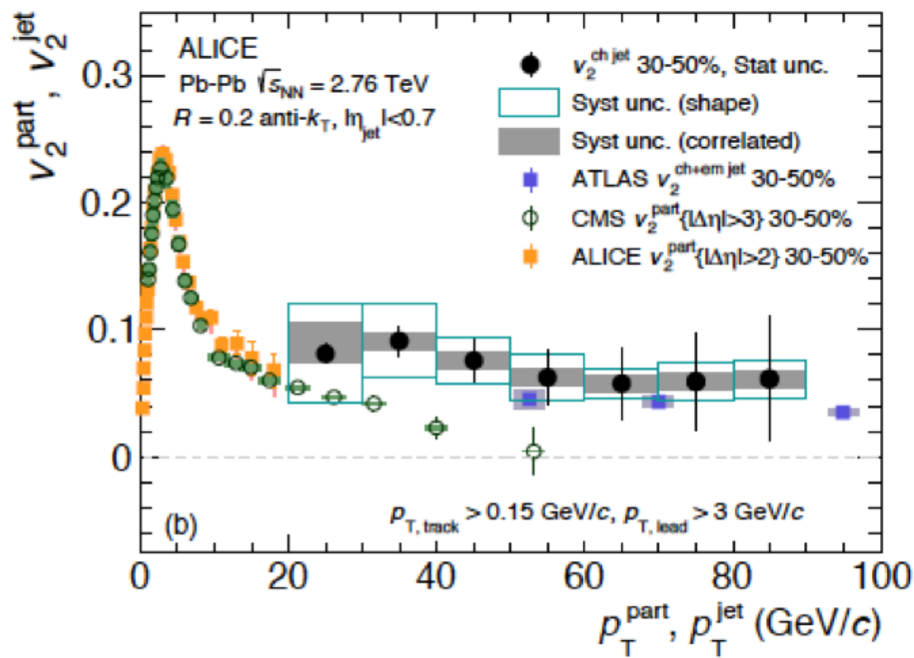
PLB 746(2015) 1



JHEP 1509 (2015) 170



PLB 753(2016) 511



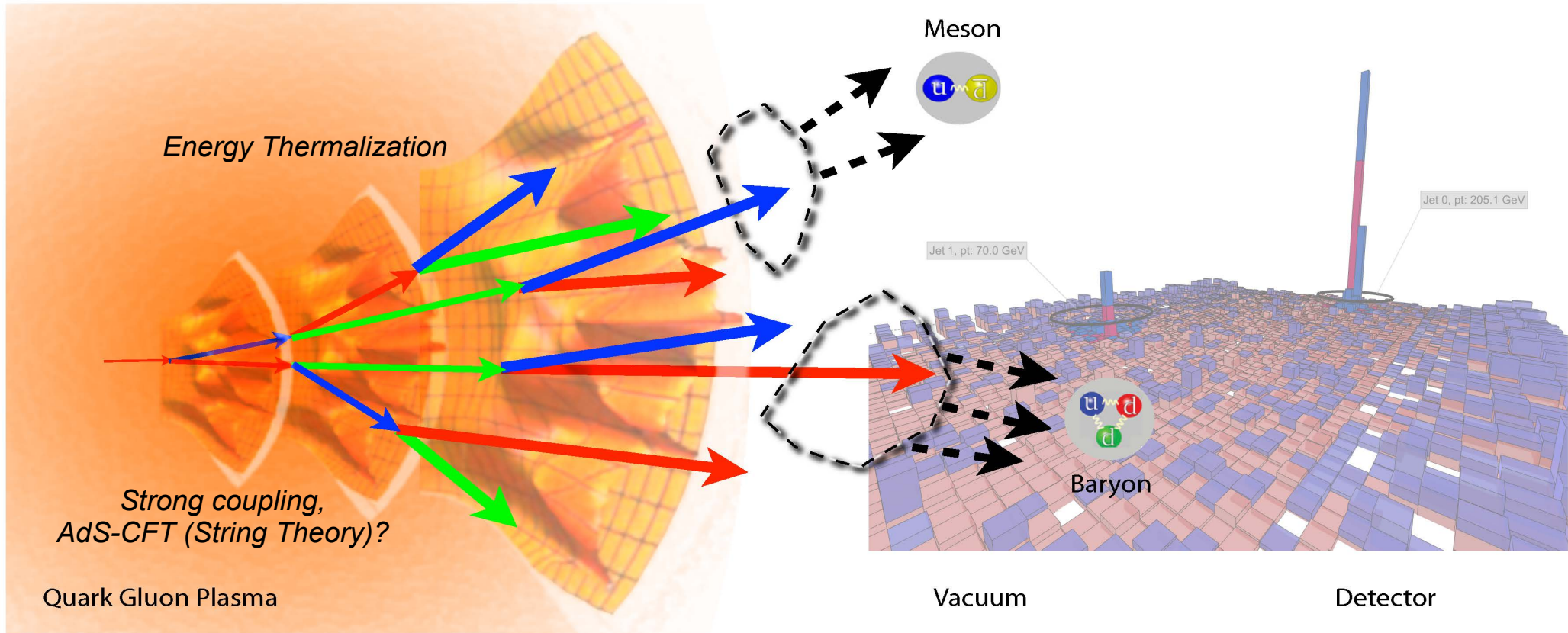


Jet Quenching in the QGP

perturbative QCD (pQCD, weak coupling)

$$Q_0^2 \gg Q_1^2 \gg Q_2^2 \gg \dots$$

$$S_0^2 \ll S_1^2 \ll S_2^2 \ll \dots$$



(Qualitative) Consistent pQCD-type radiative jet energy loss picture at RHIC and the LHC

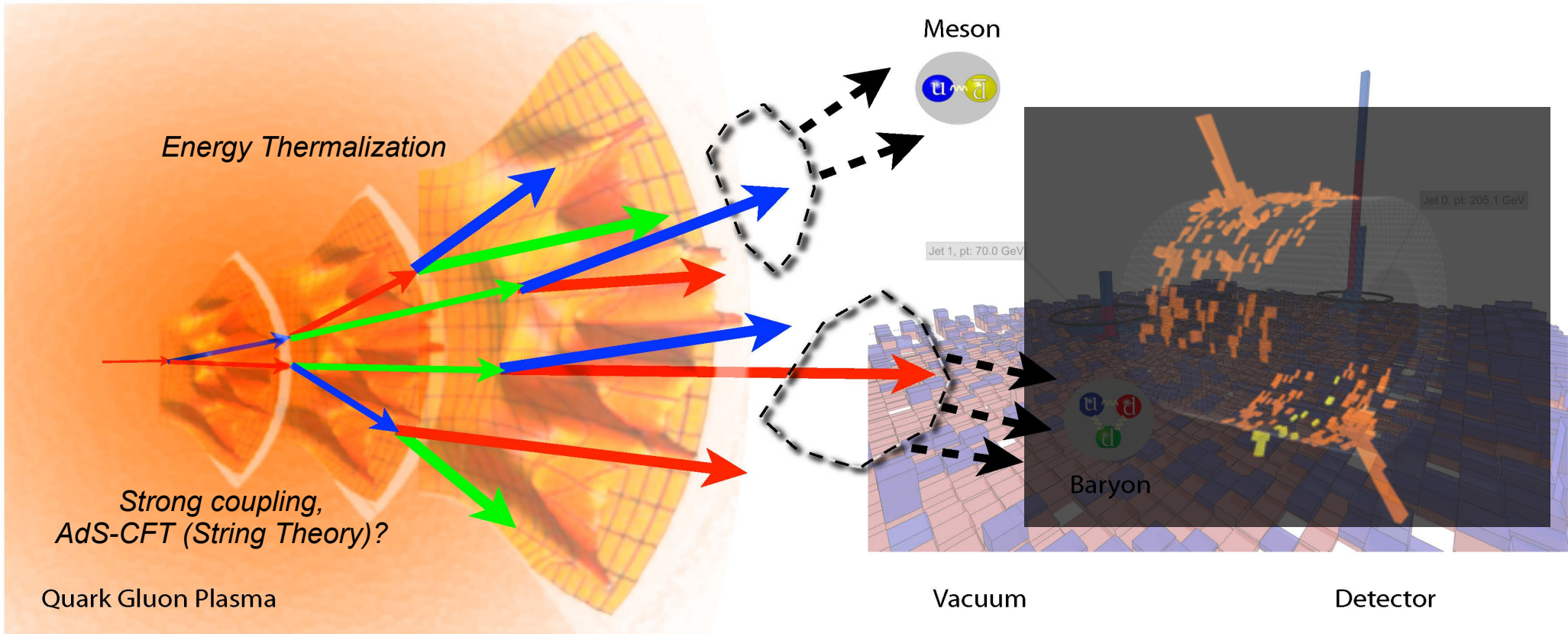


Jet Quenching in the QGP

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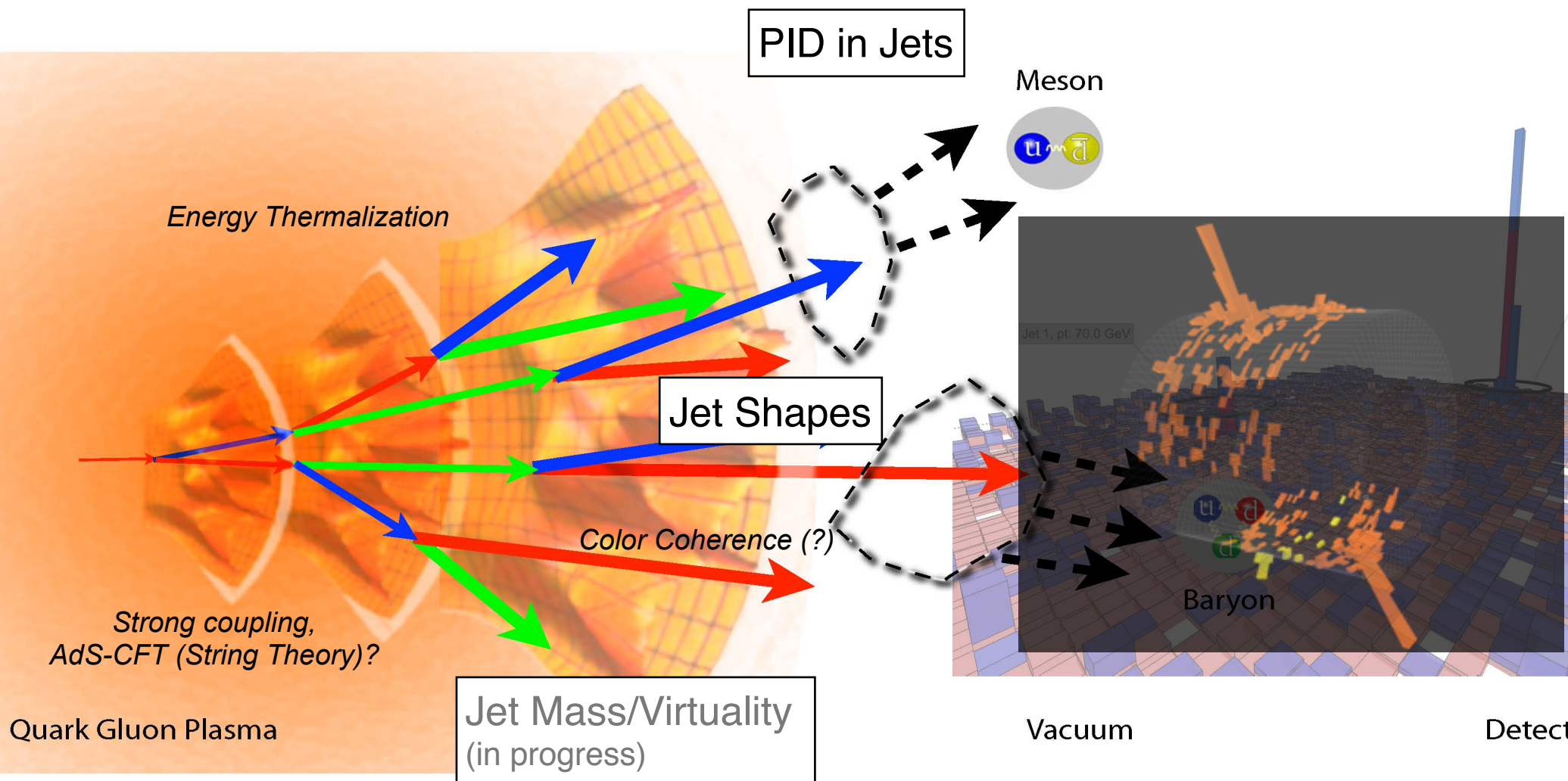
$$S_0^2 \ll S_1^2 \ll S_2^2 \ll \dots$$



(Qualitative) Consistent pQCD-type radiative jet energy loss picture at RHIC and the LHC

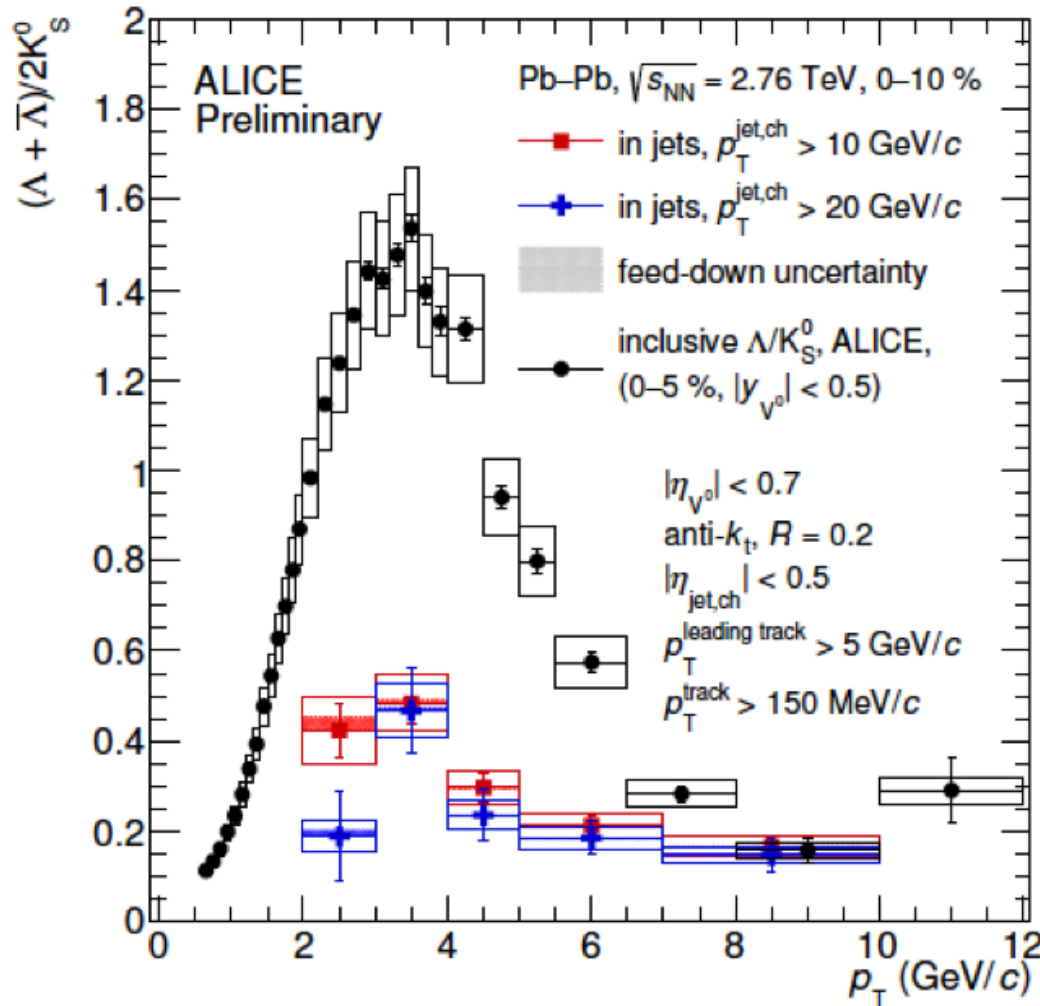


Jet Quenching in the QGP - ALICE Measurements





(Light flavor) PID in Jets in PbPb



ALI-PREL-93799

Unique capabilities in ALICE at the LHC!
Important measurement in pp in itself!

Lambda to K ratio in jets significantly lower than inclusive; consistent with pp/Pythia expectations

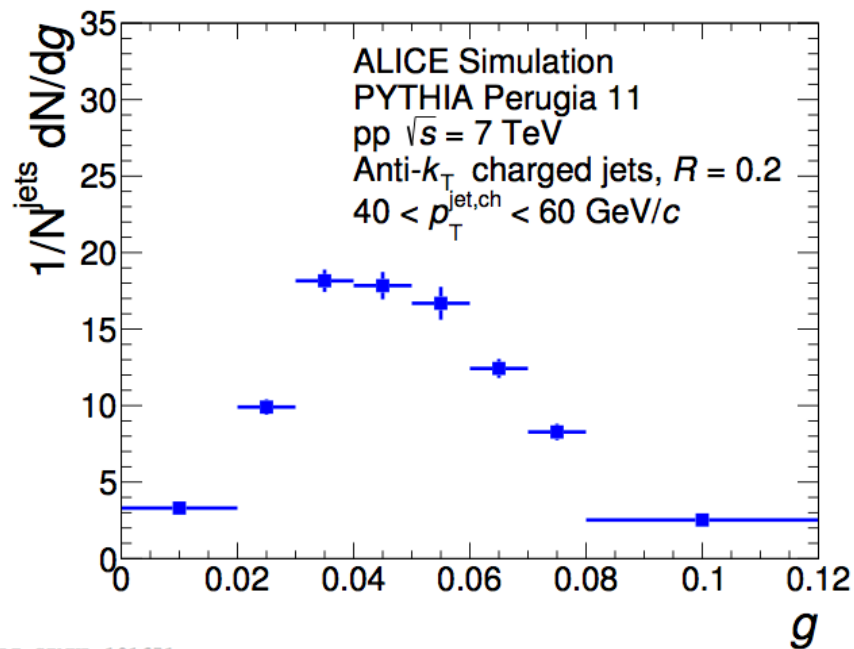


Jet Shapes

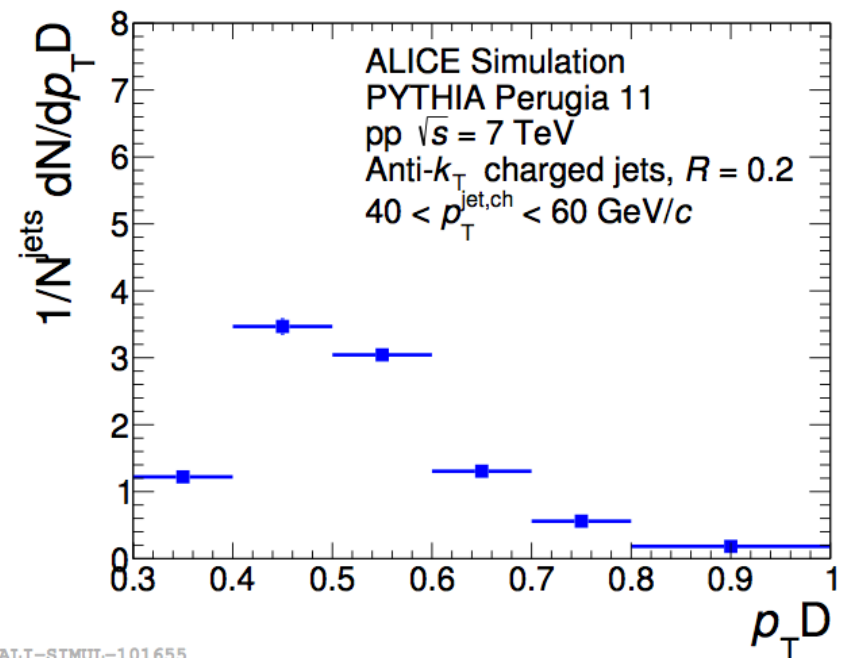
$$g = \sum_{i \in \text{jet}} \frac{p_T^i}{p_T^{\text{jet}}} |r_i|$$

r_i is distance between
Constituent i and jet axis

$$p_T D = \frac{\sqrt{\sum_i p_{T,i}^2}}{\sum_i p_{T,i}}$$



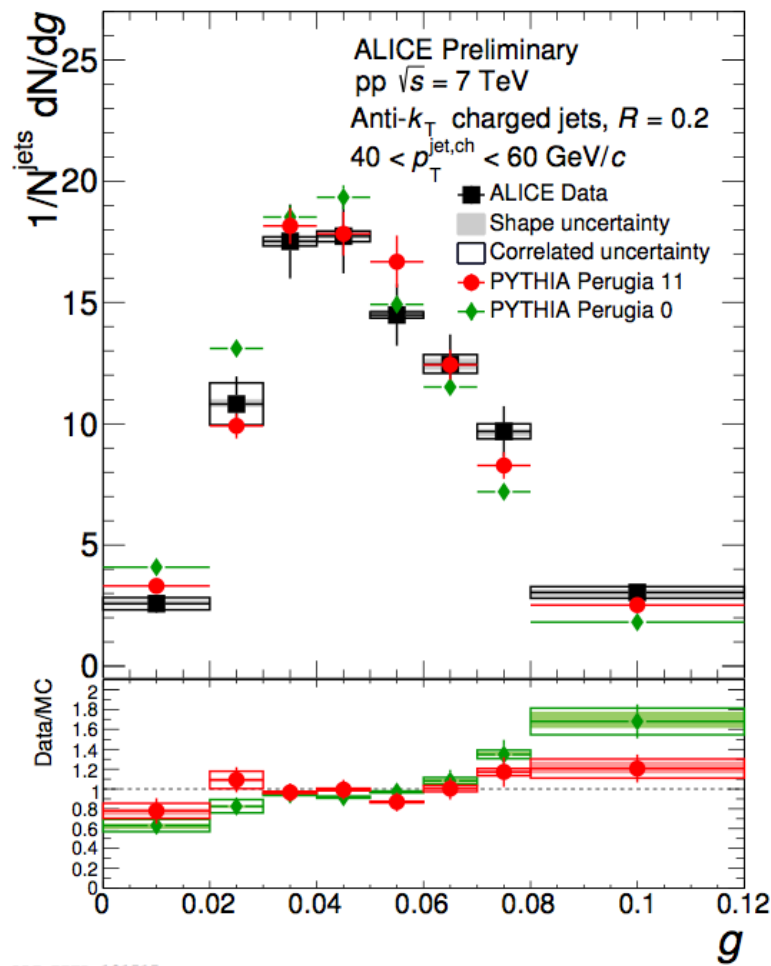
Radial moment (g) is a p_T weighted **width of the jet**:
collimated jets have lower g



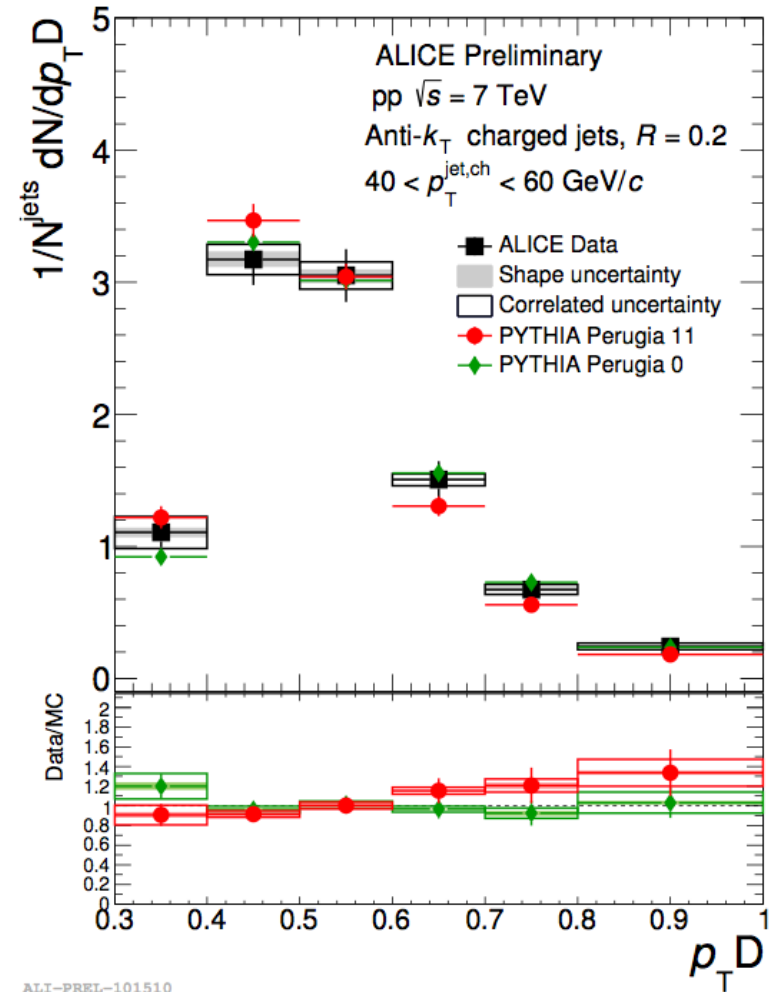
$p_T D$ measures the **dispersion** of the
constituents in the jet: jets with
fewer constituents give higher $p_T D$



Jet Shapes in pp



ALI-PREL-101515

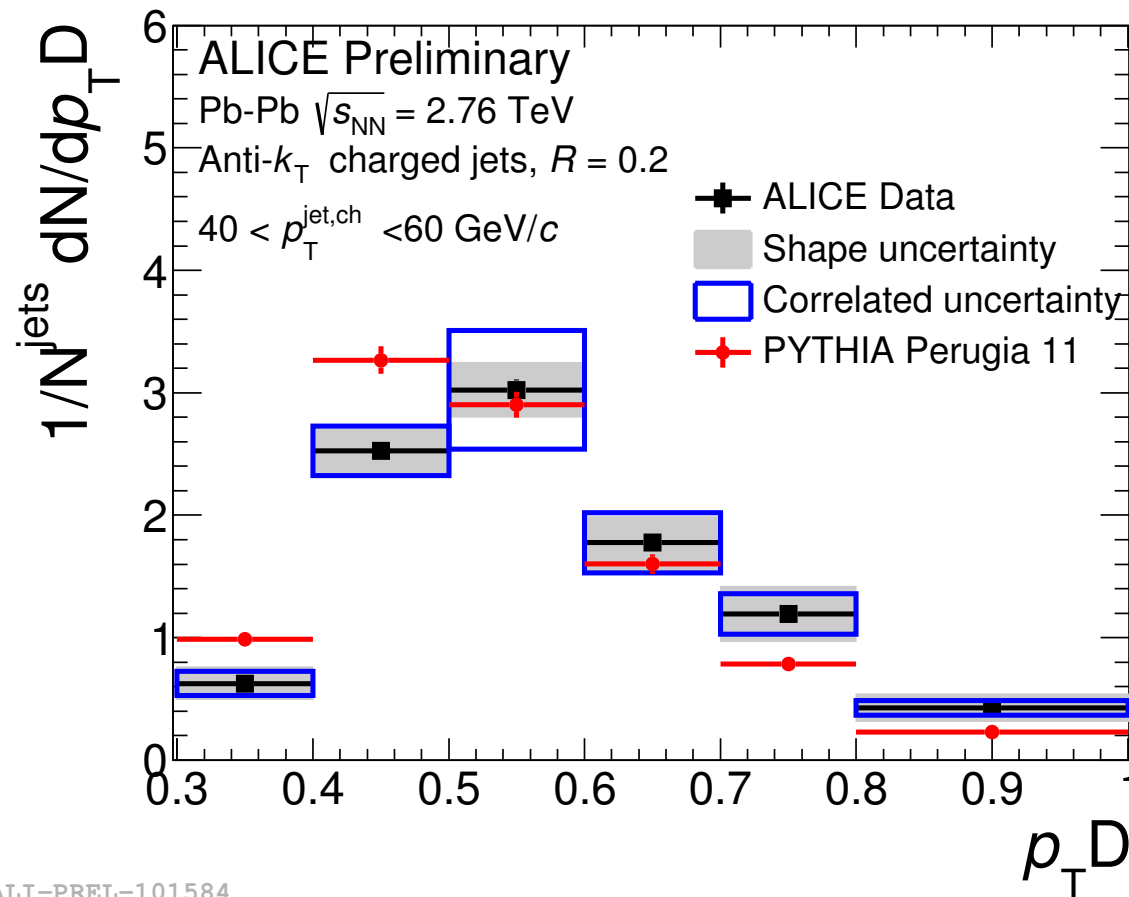


ALI-PREL-101510

Validated PYTHIA reference with data from 7 TeV pp collisions
Important QCD measurement in pp collisions in itself!



Jet Shapes in PbPb

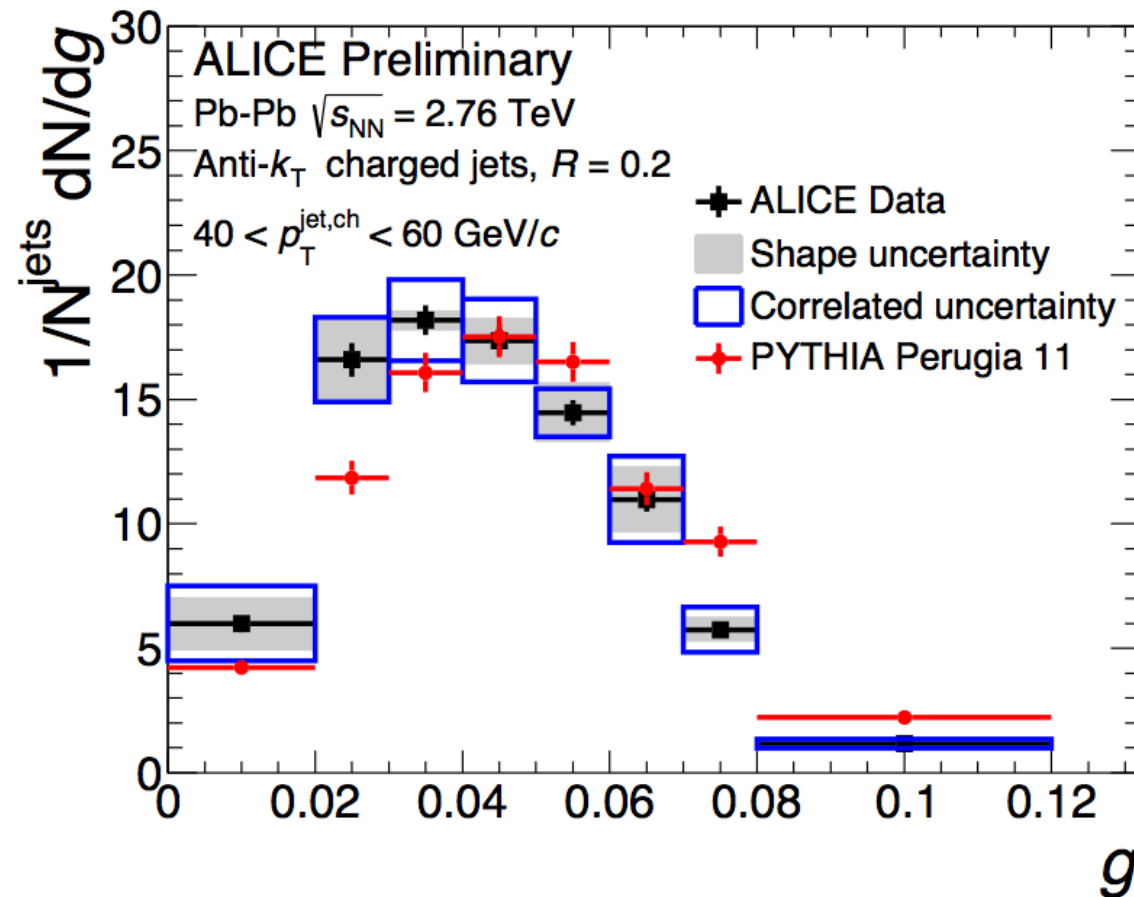


$p_T D$ shifted to higher values in PbPb wrt to Pythia

→ Indication of fewer jet constituents and larger p_T dispersion in PbPb!



Jet Shapes in PbPb



ALI-PREL-101580

p_{TD} shifted to higher values in PbPb wrt to Pythia

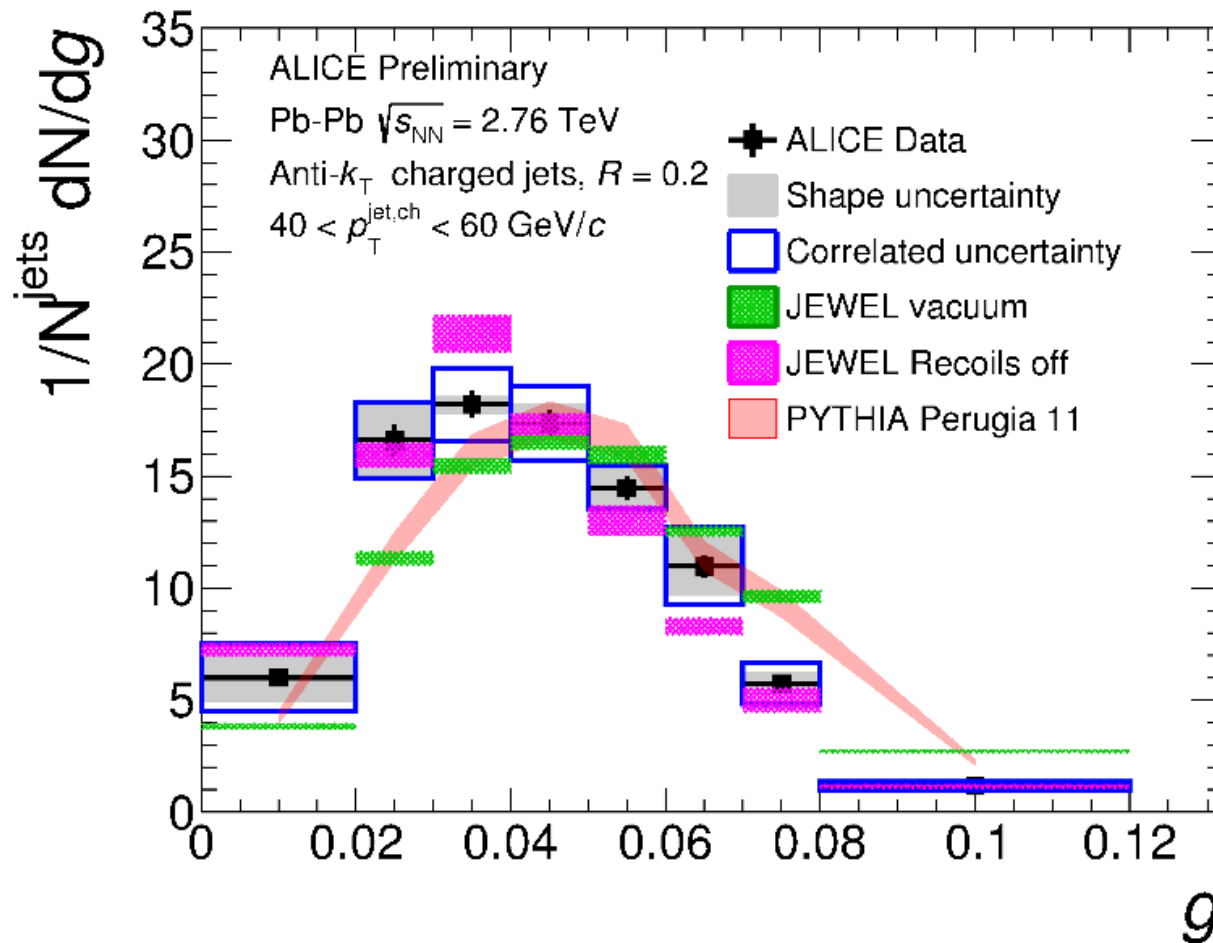
→ Indication of fewer jet constituents and larger p_T dispersion in PbPb!

g shifted to smaller values in PbPb wrt to Pythia

→ Indication of more collimated jet cores ($R=0.2$) in PbPb!



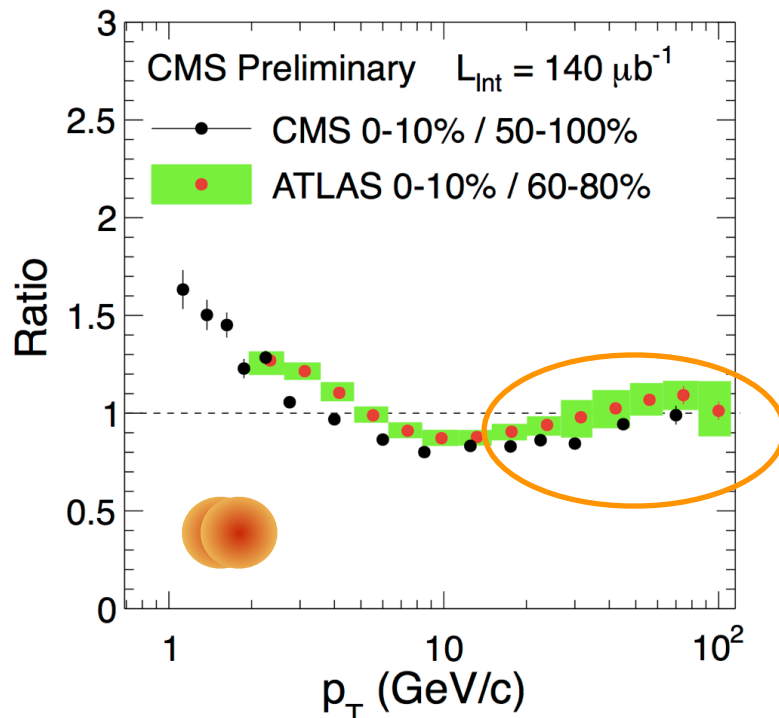
Jet Shapes in PbPb: Model Comparison



**Qualitative agreement with JEWEL Simulations;
Jet core more collimated - soft particles emitted at “large” angles**



Jet Shapes, Virtuality and (Jet) Fragmentation Functions (FF) ...



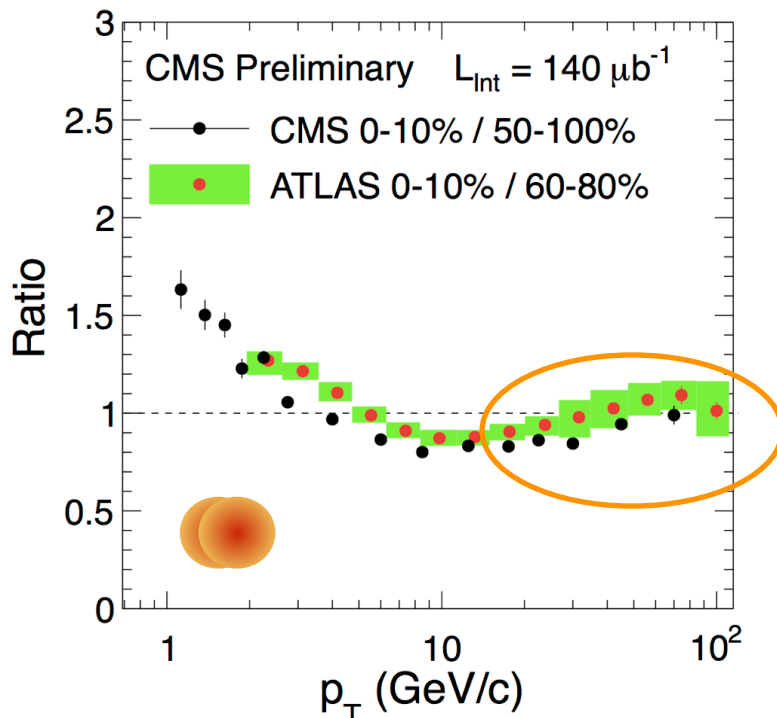
FF ratio @ high $z \rightarrow 1$

Jet Shapes indicate collimation

→ Consistent with radiative energy loss picture?



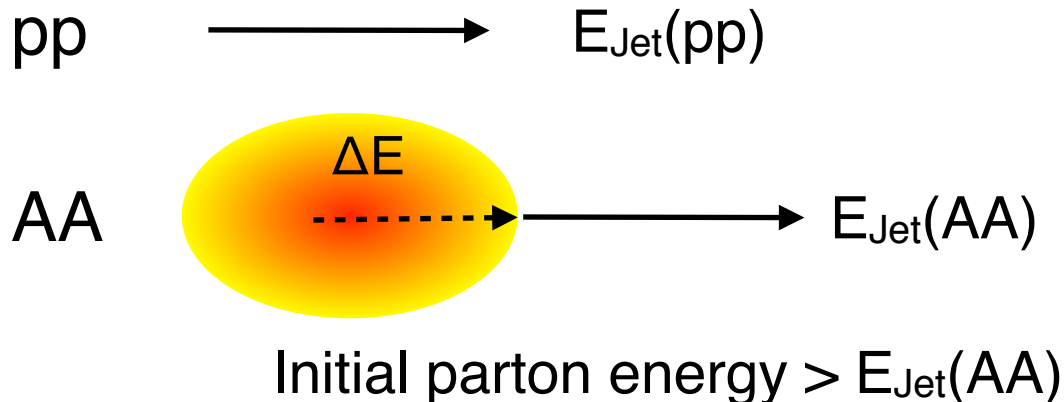
Jet Shapes, Virtuality and (Jet) Fragmentation Functions (FF) ...



FF ratio @ high $z \rightarrow 1$

Jet Shapes indicate collimation

\rightarrow Consistent with radiative energy loss picture?



In FF measurements:

$$E_{\text{Jet}}(\text{pp}) = E_{\text{Jet}}(\text{AA})$$

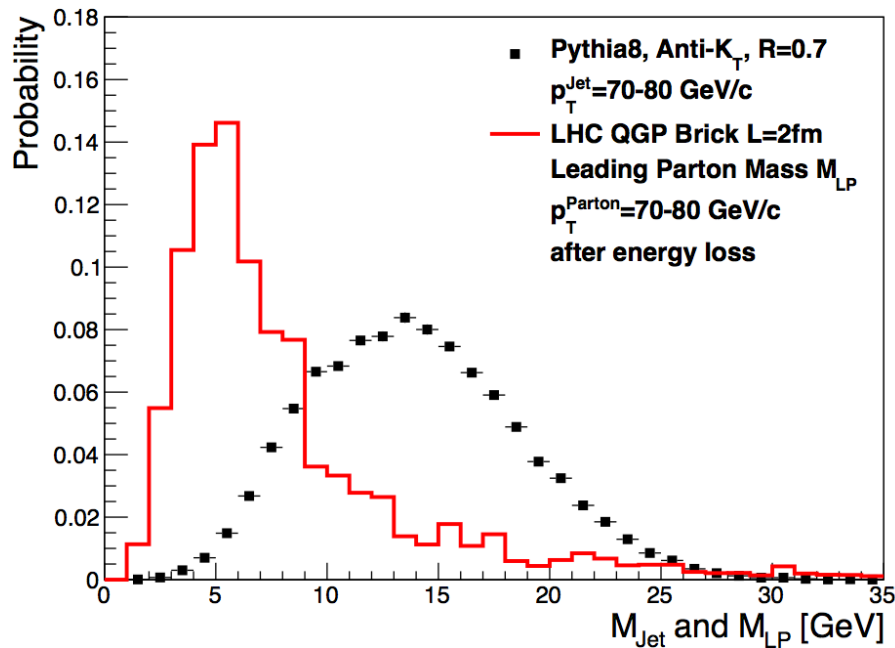
(only small enhancement of jet energy at low- z , few %)

But what about the virtuality of the (leading) parton after energy loss in the medium?

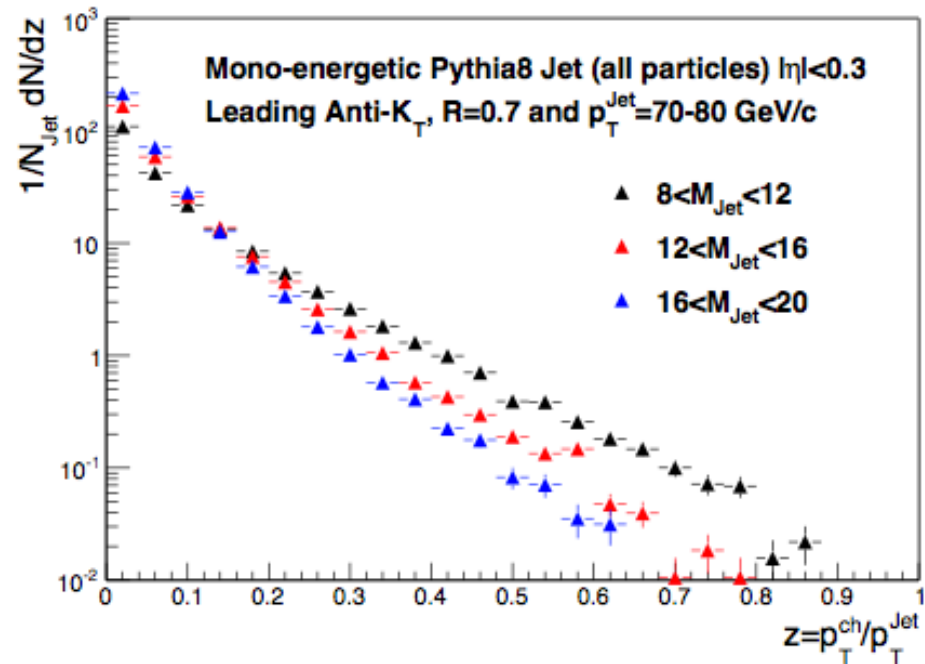


Importance of Virtuality/Jet Mass

$$M_{\text{Jet}} = \sqrt{E_{\text{Jet}}^2 - p_{\text{Jet}}^2} \propto \text{Virtuality}$$



A. Majumder and JP, [arXiv:1408.3403](https://arxiv.org/abs/1408.3403)



Comparing jets in AA with pp with the same (reconstructed) energy might not be sufficient: *not comparing apples-with-apples*

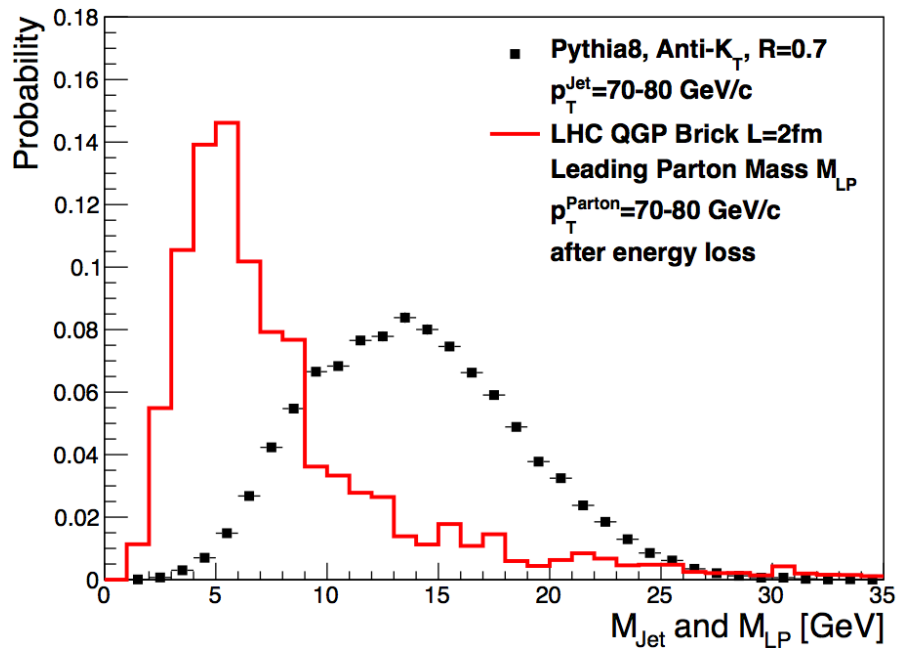
Leading parton after escaping the medium expected to have lower virtuality/jet-mass → will fragment harder wrt pp!

→ Jet Mass measurements at the LHC necessary ... (in progress)



Importance of Virtuality/Jet Mass

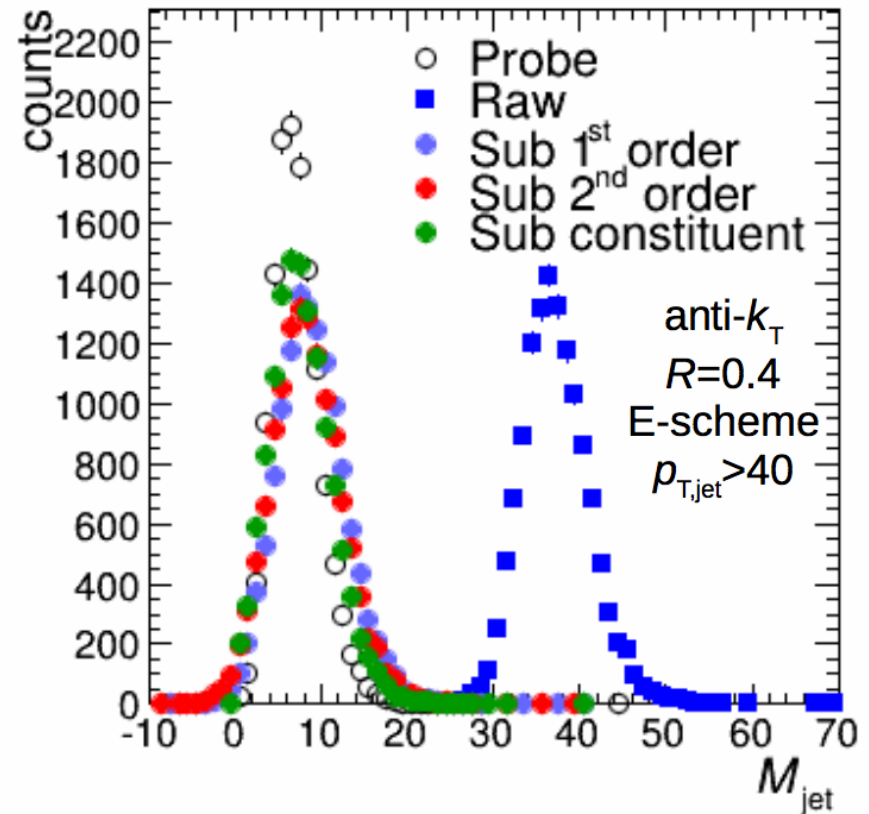
$$M_{Jet} = \sqrt{E_{Jet}^2 - p_{Jet}^2} \propto Virtuality$$



Comparing jets in AA with pp with
 might not be sufficient: not comparable

Leading parton after escaping the
 lower virtuality/jet-mass → will fra

M. Verweij (2015); Toy model simulations



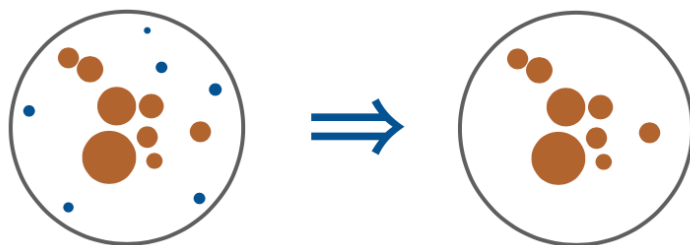
Jet shape derivative method (area based):
 Soyez et al. arXiv:1211.2811

Constituent subtraction:
 Berta et al. arXiv:1403.3108

→ Jet Mass measurements at the LHC necessary ... (in progress)

New idea

Soft Drop on One Slide

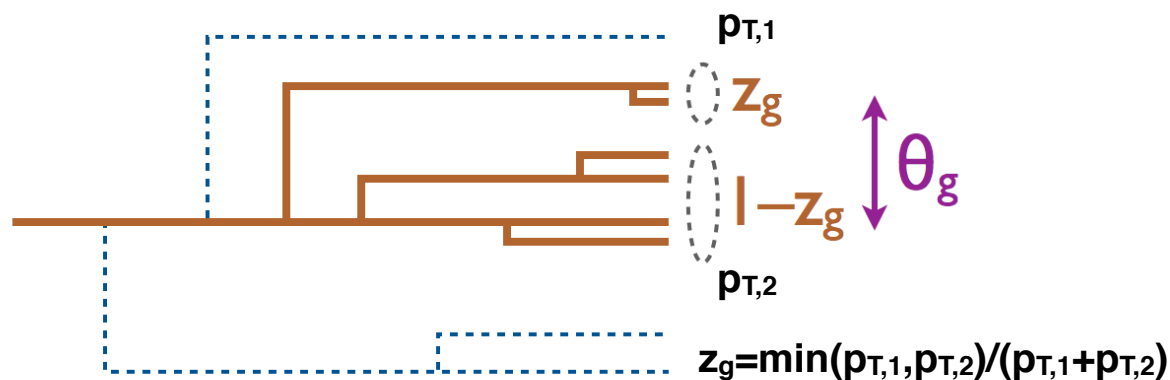


Soft Drop Condition:

$$z > z_{\text{cut}} \theta^\beta$$

↑ energy threshold ↑ angular exponent

Recursively drop wide-angle soft radiation



Based on declustering an angular-ordered tree

Final jet looks like QCD splitting function

$$\int \frac{d\theta}{\theta} dz P(z)$$

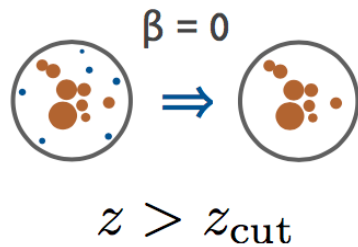
AP splitting function

β parameter gives nice handle

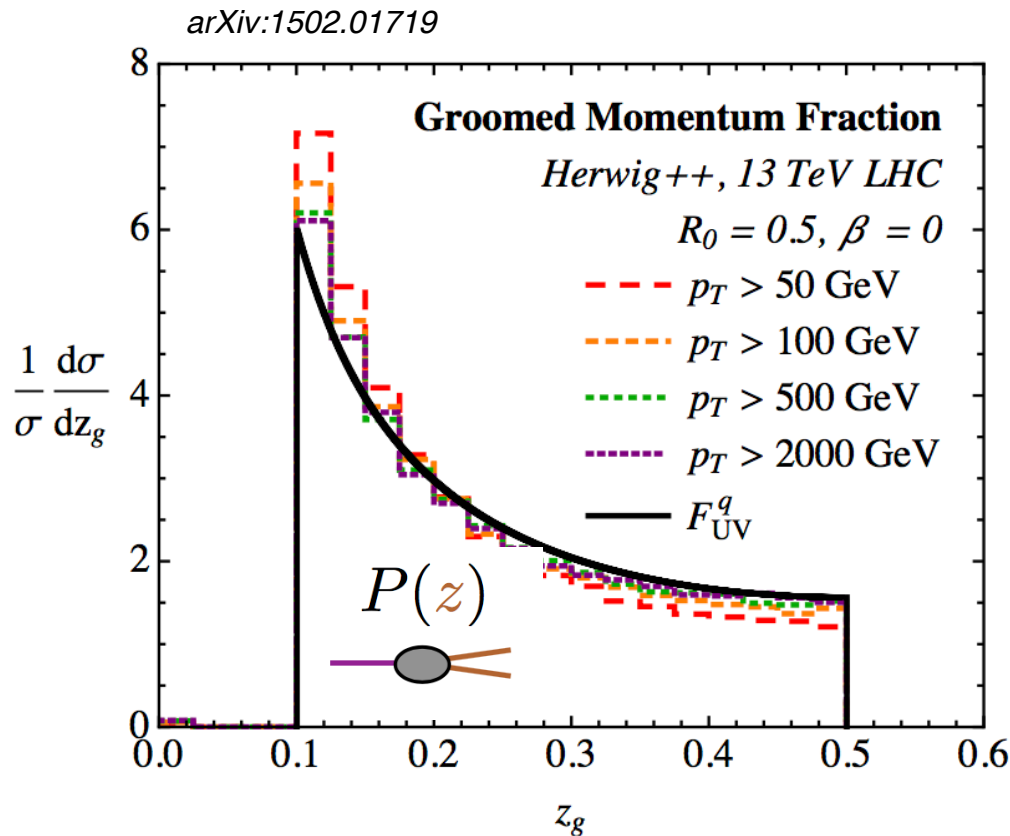
[Larkoski, Marzani, Soyez, JDT, 1402.2657]
 [see also Butterworth, Davison, Rubin, Salam, 0802.2470; Dasgupta, Fregoso, Marzani, Salam, 1307.0007]



New idea: Measuring the QCD Splitting Function (in HI)



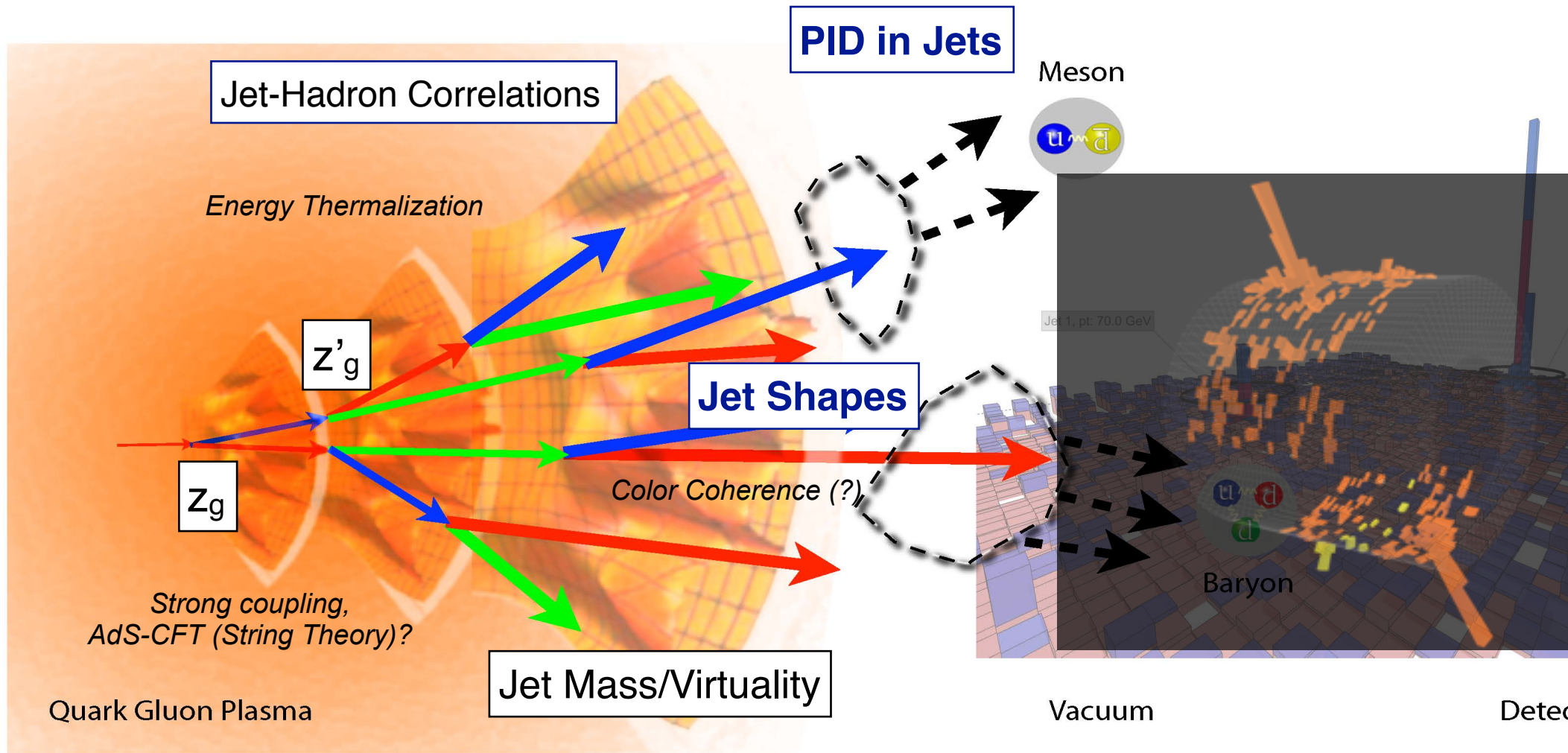
$$\frac{1}{\sigma} \frac{d\sigma}{dz_g} = \frac{\bar{P}_i(z_g)}{\int_{z_{\text{cut}}}^{1/2} dz \bar{P}_i(z)} + \dots$$



- ~ independent of α_s
- ~ independent of jet p_T ($> 30 \text{ GeV}$)
- ~ same for quark and gluon



Summary and Path Forward for Run II



**Increased jet kinematics in ALICE in Run II and new jet observables
→ study color coherence; explore transition from weak to strong
coupling; explore the microscopic nature of the QGP ...**